The Journal of Thoracic Surgery

VOL. 30 AUGUST, 1955 NO. 2

Original Communications

REDUCED INTRATHORACIC CIRCULATION AS AN AID IN ANGIOCARDIOGRAPHY

AN EXPERIMENTAL STUDY

I. BOEREMA, M.D., AND J. R. BLICKMAN, M.D.
AMSTERDAM, THE NETHERLANDS

THANKS to great technical improvements, angiocardiography has become, in latter years, an indispensable diagnostic procedure. Rapid serial exposures, in two planes, if necessary, have made this method almost a routine matter.

It must be conceded, however, that under the present circumstances, when diagnostic investigations are requested in regions close to the heart, the number of difficulties encountered increase with the proximity to the heart.

These difficulties may be summed up as follows:

1. The velocity of the blood stream in heart and major vessels is such that the injected contrast medium is rapidly dispersed. A rapid injection under high pressure is therefore necessary. High percentages of iodine are indicated in order to achieve adequate contrast. If these contrast media inadvertently reach the organs before being dispersed, serious complications may follow. Accidents involving the cerebrum, kidney, and coronary vessels have been described.

2. The contrast medium is carried off very rapidly by the blood stream. This makes high-powered, expensive apparatus an absolute necessity. Even serial exposures of 12 per second do not always give adequate information.

3. Sharp contours are extremely difficult to obtain owing to the great mobility of the walls of the heart and vessels during the cardiac cycle. Very short exposure times do not prevent a certain haziness.

4. Quick injection necessitates pressures well over the normal systolic pressure present in the vessels. Whether any untoward effects may be expected from these sudden increases in pressure is not known.

From the Surgical Clinic of the University of Amsterdam at the Wilhelmina Gasthuis; Chief: Prof. Dr. I. Boerema.

This experimental work was made possible by the financial aid of Toegepast Natuurwetenschappelijk Onderzoek.

Received for publication Feb. 18, 1955.

These difficulties, however, would cease to exist if it were feasible to reduce the blood flow through the heart for a short period. If the blood flow would cease or be greatly reduced, little or no dispersal of the contrast medium would occur, and the time in which injection and exposures could be made would be longer. The use of highly concentrated contrast media could be abolished, reducing the danger of the above-mentioned complication. Reducing the blood flow through the heart would lower the blood pressure, which in its turn would make injection under high pressure unnecessary. The possible danger of increased intra-arterial pressure—in sometimes already diseased blood vessels—must be borne in mind.

In order to slow down or completely interrupt the blood flow through the heart and the great vessels near this organ, we applied knowledge gathered during the last three centuries concerning the influence of the respiration on the blood flow in the thorax.

Swammerdam in the seventeenth century believed that alternating inspiration and expiration were necessary for maintaining the blood flow in the capillaries of the lungs.

During the first half of the nineteenth century there were conflicting views concerning the influence of respiration on the blood flow in the thorax. Some investigators concluded from experiments that cessation of normal respiration was followed by a fall in blood pressure, while others were of the opinion that such respiratory arrest had no influence on the blood pressure and the frequency of the heartbeat, as estimated from the radial pulse.

Weber in 1850 found an explanation for these contrasting views. According to him, they were dependent on whether the glottis was open or closed during cessation of respiration. When the glottis was open, there was no interference with the blood flow. When, however, the glottis was closed after an inspiration, the expiratory muscles compressed the thorax, so that the organs within it were also compressed. This had a great influence on the blood stream. From experiments on himself he showed that compression of his own thorax, after deep inspiration and closure of the glottis, was followed almost immediately by complete disappearance of the radial pulse. The heartbeat disappeared immediately, whereas the radial pulse could still be felt weakly for 3 or 5 beats before disappearing totally. Weber concluded that compression of the contents of the thoracic cavity and of the air-filled lungs caused cessation of the heartbeat and almost immediate disappearance of the pulse.

Weber in the experiment on his own body compressed the air in the lungs and in the bronchi. He concluded not only that this gave an impetus to the blood stream through the capillaries of the lungs, but also that the pressure on the lungs, because of their elasticity, was brought to bear upon the heart and the great vessels. The right atrium and the venae cavae were especially compressed and the tension of the blood in them was thereby raised, so that a damming up of the venous blood stream in the great veins outside

the thorax resulted. Normally the pressures in the venae cavae and the right atrium are so low that even the low pressure in the great veins is sufficient to bring the blood into the right atrium. Therefore, during compression of the thorax after inspiration with a closed glottis, there is no filling of the heart and the flow through the right heart is blocked. The first following heartbeats will still pump the blood that comes from the lung vessels to the left heart, into the aorta, and after this the flow into the left heart is blocked also. This is the explanation for the 3 or 5 weak radial beats which may be felt after the beginning of the compression of the thorax. Immediately after compression of the thorax was discontinued and the glottis was again open, the normal pulse reappeared.

Weber confirmed the view of Valsalva, who in the seventeenth century wrote: "If after a deep inspiration, a strenuous and prolonged expiratory effect be made against a closed glottis, the pressure so exerted on the heart and greater vessels arrests the flow of blood through the lungs." But Weber went further and stated that not only the blood flow through the lungs was arrested, but also, and primarily, the flow through the intrathoracic venae cavae and the right heart was arrested; it is thus primarily a true tamponade of the right heart. The observation of Valsalva drew no attention for two centuries, but the writings of Weber, who was unaware of Valsalva's discovery, was the cause of many experimental, clinical, and pathological papers on this subject, even up to the present day.

Ten years after Weber's communication, Einbrodt (1860) showed by animal experiment that increasing the pressure in the lungs by blowing air in the trachea produced the same result as blocking the blood flow from the venae cavae and the right heart by use of the Valsalva test in men.

Sauerbruch's explanation of the Valsalva test was that it was due to a blocking of the blood flow through the lungs by compression of the smaller blood vessels in the alveolar walls. He thought that the pressure exerted on these vessels was the same as the pressure of the intrabronchial air and that the pressure on the heart and great vessels was the tension of the intrabronchial air minus the contractile force of the elastic lung tissue.

Humphreys and associates (1937) showed in experiments on dogs that the cardiac output decreased when the intratracheal pressure was increased. These workers measured the blood pressure in the heart and in the great vessels. From their experiments they believed that the decrease in cardiac output was caused by compression of the right heart interfering with its filling, rather than by compression of the pulmonary vessels interfering with the emptying of the lung vessels. This was an experimental confirmation of the deduction of Weber, formulated nearly a century earlier.

Our roentgenological research on this problem now shows that Weber was exactly right; that high intrabronchial pressures do not block the blood flow through the lungs, but compress the right heart and the venae cavae. It is strikingly remarkable that Weber, from his simple experiment, was able to describe the sequence of events occurring in the thorax, which can now

be demonstrated with the aid of operative experimental surgery and of roentgenology. No important addition could be made to Weber's deductions. Making use of this knowledge, we intended to fill the heart and the large intrathoracic vessels with a radiopaque fluid during the slowing down or even the arrest of the blood flow as described by Valsalva and Weber.

However, before starting this study in the field of roentgenology, we first tried to verify the fact that the fall in arterial blood pressure which accompanied an elevation of intrabronchial air pressure was not due to compression of the capillary bed in the lungs (as was the opinion of Sauerbruch), but that the tamponade or blocking of the venae cavae and the right heart was the primary cause (as was the meaning of Weber). If the first concept were correct, then increasing the intrapulmonary air pressure might give rise to an acute cor pulmonale, bringing the right heart of the patient into a precarious state. Furthermore, a greatly increased intrathoracic pressure might prove a danger because of the anemic state of all organs during this period of lowered blood flow. Heart and brain particularly might be damaged. Weber stated that when he continued his experiment for more than sixty seconds he became completely unconscious. He also thought that complete arrest of the blood stream might be extraordinarily dangerous. Weber ascribed to this mechanism many cases of suicide due to cessation of respiration.

The Valsalva test in man differs greatly from the condition caused by insufflation of air into his lungs. The Valsalva test and also the "fitness" test (Flack) of blowing against a column of mercury of 40 to 60 mm., necessitate a forceful contraction, not only of the thoracic muscles, but also of the muscles of the abdominal wall. Under such conditions the diaphragm is not an essential septum between the abdominal and the thoracic cavity. When air is inflated into the lungs of an anesthetized animal only the thoracic cavity is involved. The blood flow from the abdomen to the thorax must be quite different in both conditions (Nordenfeld).

We now know that the blood stream to the heart and brain can be blocked for 2 to 4 minutes without danger; therefore, a block for 30 to 60 seconds, as in our experiments, would not be expected to be dangerous at all. Nevertheless, we tried to elucidate the following points by animal experiment, before starting our roentgenologic study:

1. Does an intrabronchial pressure increased to 60 cm. water diminish the blood flow from the left heart sufficiently for our purpose?

2. How does the blood pressure in the right heart react to such an increased intrabronchial pressure? Is the decrease in left ventricular output to be attributed to compression of the pulmonary capillary bed or to a decreased filling of the right ventricle when the intrabronchial pressure is raised to 60 cm. water? In other words, does danger of acute cor pulmonale exist?

3. Does the danger of myocardial ischemia exist within a time limit of 60 seconds or after repeated drops in blood pressure?

4. Is it technically feasible to inject the contrast medium in a period of suppressed circulation? Does a smaller amount of contrast medium containing a smaller percentage of iodine give better results than methods currently employed?

5. Does this method give better information about conditions existing in the circulatory system?

The answers to these questions follow in numerical order.

1. Anesthesia was started with intravenous veterinary Nembutal. The trachea was intubated with a cuffed tube. A water manometer was placed in the anesthetic circuit, so that exact control of the pressure exerted by manual compression of the bag was possible. Through the right carotid artery a polyethylene catheter (exterior diameter 3 mm.) was passed into the

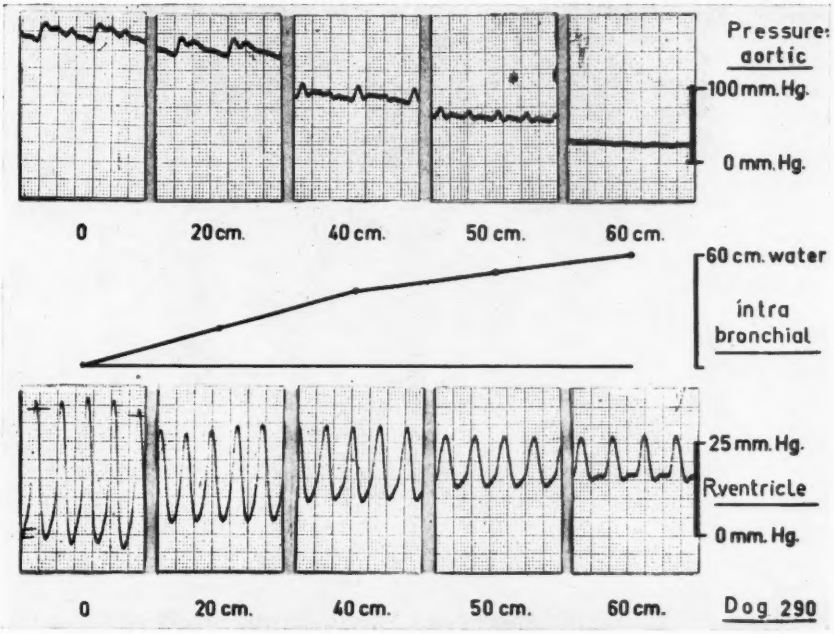


Fig. 1.—Pressure readings in aorta and right ventricle with increasing intrabronchial pressure.

ascending aorta. Direct blood pressure readings were obtained with increasing intrabronchial pressure (Fig. 1). Until the intrabronchial pressure reaches 30 cm. water, no important changes can be seen; over 30 cm. intrabronchial pressure the blood pressure decreases rapidly, until at 60 cm. pressure no pulsations are present at a basic value of 20 mm. Hg. The first question can be answered in the affirmative. On increasing intrabronchial pressure to 60 cm. water, the left ventricular output is very much decreased.

2. In the same dog a catheter was passed down the right jugular vein into the right ventricle. Blood pressure readings were taken with increasing

intrabronchial pressure. Fig. 1 shows the decreasing pressure in the right ventricle with mounting diastolic values. The normal value of 34/−3 mm. Hg is reduced, at 60 cm. water intrabronchial pressure, to 26/14 mm. Hg. The decrease in systolic pressure in the right ventricle is gradual. This confirms the view of Humphreys that the compression of the pulmonary capillary bed cannot be an important factor responsible for the fall in left ventricular output. If this were the case, the recording of the right ventricular pressure would show a sharp rise. We must conclude from this that the increasing pressure in the trachea to 60 cm. water impedes the filling of the right heart.

The elevation of the diastolic pressure must be assumed to originate from the elevated pressure in the entire thoracic cavity. To demonstrate the influence of the elevated intrathoracic pressure the following experiment was performed.

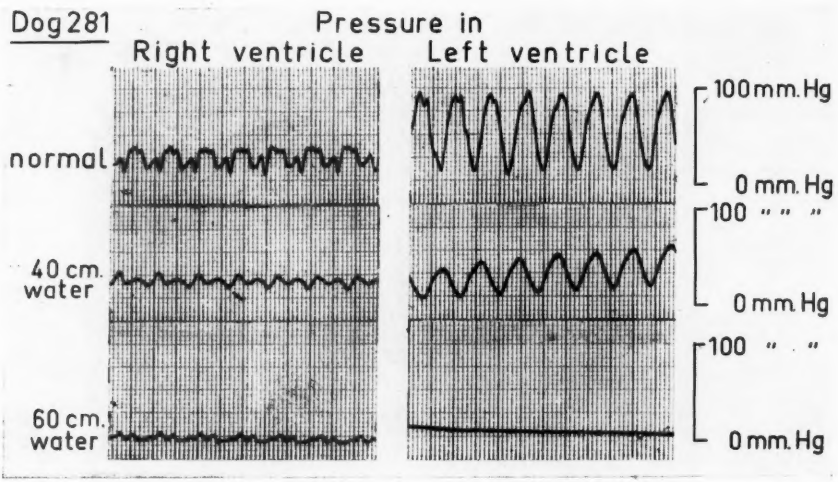
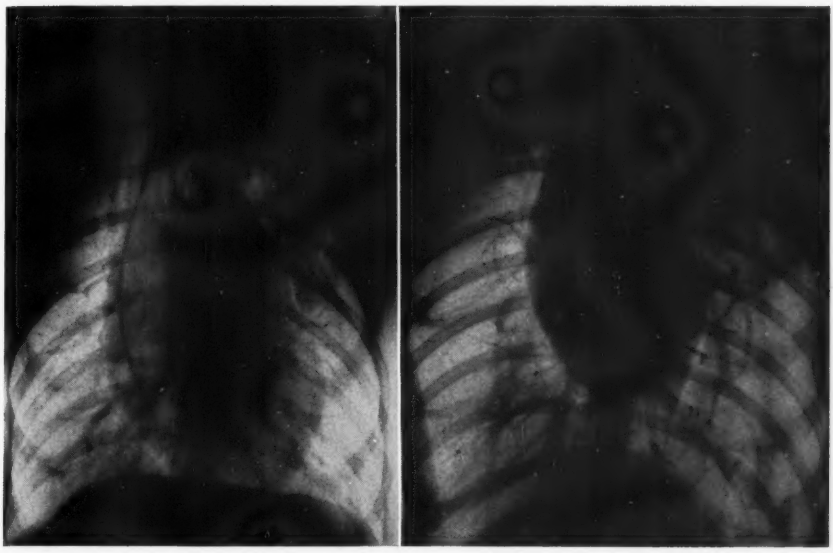


Fig. 2.—Right and left ventricular pressures after left-sided thoracotomy at normal pressure in the bronchi and at pressure of 40 cm. and 60 cm. water.

A left-sided thoracotomy through the fifth intercostal space was performed in a dog. The pericardium was opened. A needle, connected to an Elema pressure recorder, was introduced into the left ventricle. The left lung was loosely packed with gauze. Intrabronchial pressure was raised to 40 cm. water (Fig. 2). The left ventricular pressure decreased to 50/15 mm. Hg. After raising the intrabronchial pressure to 60 cm., the pressure was further decreased to 5 mm. Hg. Release of intrabronchial pressure showed a prompt return to normal values. The recorder needle was further advanced through the ventricular septum into the right ventricle and readings were taken under the same conditions. The decrease in systolic pressure was evident, the diastolic values were not elevated.

Apart from the evidence provided by these pressure recordings that acute cor pulmonale need not be feared, roentgenologic evidence is also present. Fig. 3 shows the heart contour under normal conditions and with elevated intra-



A. *B.*

Fig. 3.—Heart shadow with catheter in right ventricle under normal conditions (*A*), and with intrabronchial pressure raised to 60 cm. of water (*B*). The compression of the heart in the latter is evident.

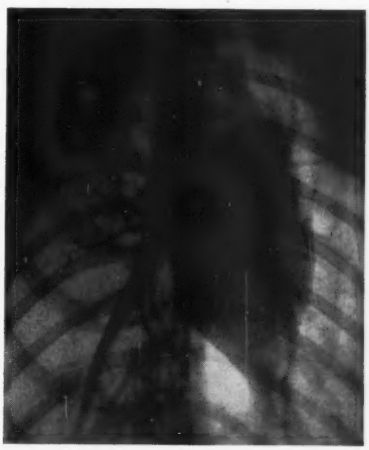
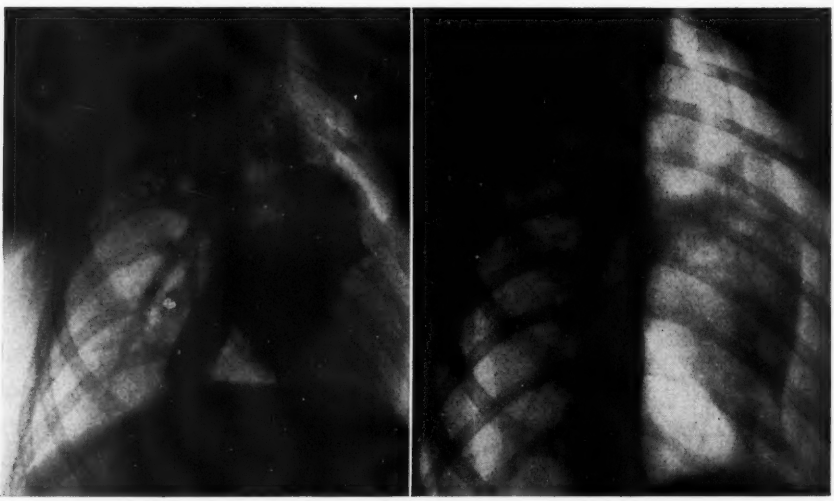


Fig. 4.—Right ventricle during injection of contrast medium with raised intrabronchial pressure. The pulmonary vessels are clearly shown and not blocked by the high intrabronchial pressure.

bronchial pressure. The right ventricle remains small when contrast medium is injected (Fig. 4). The difference in size of the inferior vena cava under normal conditions and with inflated lungs may be estimated from Fig. 5. It confirms Weber's statement that not only the right heart but also the venae cavae are compressed by elevation of the intratracheal pressure.

A right-sided thoracotomy through the fourth intercostal space was performed in a dog. A glass tube was inserted into the right atrium through the auricle. The average blood pressure was 4.5 cm. water; increasing the pressure of the air in the bronchi and the lungs caused the blood pressure in the atrium to rise rather high. It is clear that with the right thoracic cavity open, there was no compression of the venae cavae and the right heart; only the capillary bed in the lungs was compressed, which produced a situation as in acute cor pulmonale.



A. *B.*

Fig. 5.—Inferior vena cava under normal conditions (*A*) and with intrabronchial pressure raised (*B*). The compression of the vena cava is evident.

We conclude from these experiments that with the thoracic cavity closed (or at any rate the right pleural space) no danger of acute cor pulmonale is present when the intrabronchial pressure is raised to levels between 40 and 60 cm. of water. The venous return to the right heart under these circumstances is primarily greatly reduced.

Meyer Saklad, reviewing pressure breathing in surgery, states: "A patient in good condition can tolerate a moderate amount of increased intrapulmonary pressure. The patient in a poor physical state cannot. The ability to withstand positive pressure breathing depends to a great extent on the patient's ability to maintain a heightened venous pressure, for, during the phasic drop in intrapulmonary pressure, the elevated venous pressure is an important factor in filling the right heart."

Hypotension anesthesia might make poor candidates for pressure breathing (Saklad). These dangers, as indicated by Saklad, are caused by an elevation of the intrabronchial pressure of air during a great deal of the period of anesthesia, although interrupted repeatedly.

In our roentgenographic method, the blood flow is impeded by elevation of the intrabronchial air tension only once, and for no more than 30 to 60 seconds. It is, therefore, questionable whether the dangers, summed up by Saklad, exist in our method.

3. Nevertheless, the danger of myocardial ischemia is undoubtedly present when the left ventricular output is reduced. In most circumstances, therefore, we have performed the experiments under constant electrocardiographic control. We have raised the intrabronchial pressure during periods up to 60 seconds. Apart from a temporary reversed T wave, no changes could be observed. According to the cardiologist, the changes observed may have been due to axis deviation.

In two instances dogs were sacrificed after the experiment in order to examine the pulmonary tissue. No pathological changes were found in the alveoli and there were no signs of interstitial edema. Fourteen experiments were performed on 10 dogs. There was one death in the series, due to heavy overdosage of contrast medium in one of the first experiments. The animal died from cerebral convulsions.

The direct influence of an injection of contrast fluid into the ascending aorta through a tube passing the carotid artery was measured in the aortic arch. When under normal conditions the fluid was injected under pressure, the blood pressure was elevated during the injection by 25 to 30 mm. Hg. Using the same technique with low blood pressure caused by raised intrabronchial pressure, no pressure changes could be recorded. Thus, the danger of raising the pressure in the aorta to too high a level during the injection of contrast fluid is eliminated when the intrapulmonary air pressure is raised to 60 cm. water.

4. Nuvali, Rousthoi, Radner, Guglielmo and Guttadauro (reviewing the angiocardiographic material of Jönsson et al.), Helmsworth et al., Wickborn, Pearl, Hoyos and del Campo, have shown very encouraging results in animal experiments and in clinical research, concerning the visualization of the aortic bulb, the aortic arch, and the coronary vessels. Their chief difficulty is the selection of the correct moment for exposure, if no apparatus for serial exposures is used.

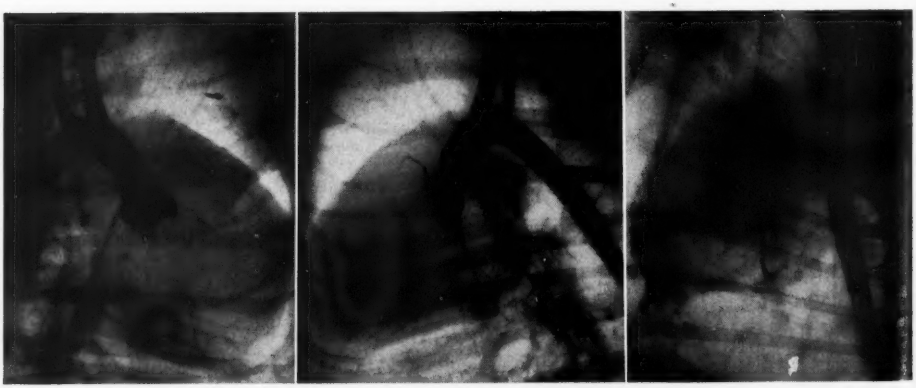
For these animal experiments we have used a very simple device, based on sliding film cassettes, with exposure times of 0, 2, 4, 7 and 11 seconds. A Lysholm grid was used. Exposure times varied from 0.04 to 0.06 second. For the injection, a pressure syringe as described by Jönsson was used, connected with a polythene catheter with an internal diameter of 2.1 mm. The catheter was placed in the ascending aorta, through the right carotid artery, at a level of 1.5 cm. above the aortic valves. The time necessary to inject 20 to 25 c.c of 45 per cent Pyelombrine was about 2 seconds. The first exposure was made

when approximately four-fifths of the total amount had been injected. The same technique was used in the dog shown in Fig. 6, *A* and *B*, with and without raised intrabronchial pressure. The difference in quality is obvious.

For cardiopneumangiography the technique used was essentially the same. The catheter was introduced through the right jugular vein into the right ventricle. When the intratracheal pressure was raised to 60 cm. water the

A. *B.*

Fig. 6.—Aortic arch after injection from brachiocervical trunk under normal conditions (*A*) and with intrabronchial pressure raised (*B*). The latter shows reduction of the size of the heart, the aorta, and the brachiocervical trunk; a sharper outlining; a better filling of the bulbus aortae; a good visualization of the aortic valves; a good filling of the coronary arteries.



A. *B.* *C.*

Fig. 7.—Coronary arteries (left and right oblique, and anteroposterior view) well-visualized after raising of the intrabronchial pressure to 60 cm. water.

contrast obtained in the pulmonary vessels with as little as 20 c.c. of 45 per cent Pyelombrine was excellent, even when the time for injection was increased to 6 seconds with the use of a small catheter. Intrabronchial pressure in some later experiments was raised to only 40 cm. water with the same excellent results. When the same techniques were used, but without raised intrabronchial pressure, no clear image could be obtained of the pulmonary vessels.

Fig. 8.—Right heart and pulmonary arteries visualized with 20 c.c. of 45 per cent contrast medium during increased intrabronchial pressure. The pulmonary veins are faintly visible.

Some experiments were carried out with high intrabronchial pressure to demonstrate the lowered arterial pressure in peripheral arteriography. It appeared impossible to obtain a filling of the femoral arteries when the contrast fluid was injected in the aortic arch. The contrast medium was retained in the abdominal aorta. Release of the intrabronchial pressure restored passage immediately. Thus, it is also possible with this technique to obtain a good contrast using only a small amount of fluid and injected under low pressure. Excellent nephrograms were obtained by this method.

We may conclude that a technical improvement is obtained by the method described. Small amounts of contrast medium containing a low percentage of iodine injected under low pressure give good results from a technical point of view.

5. By the method described, information can be obtained without the use of quick-working film changers. This makes angiocardiography possible without expensive apparatus. Filling of the aortic arch and bulb and coronary arteries is readily performed with good visibility (Fig. 6). The reduced

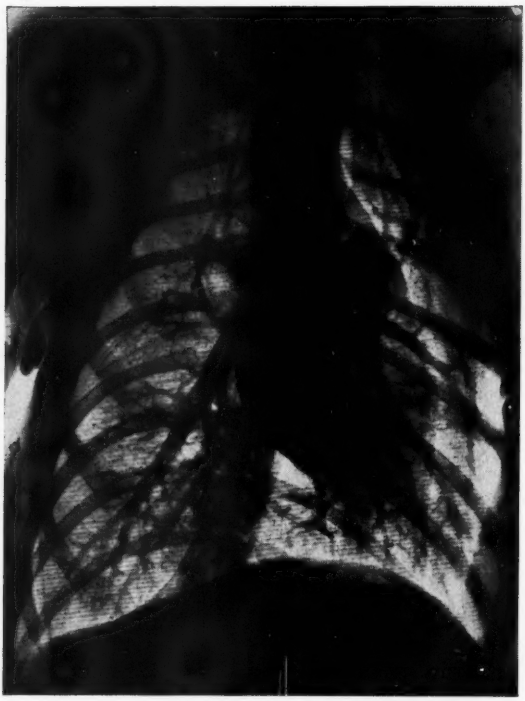
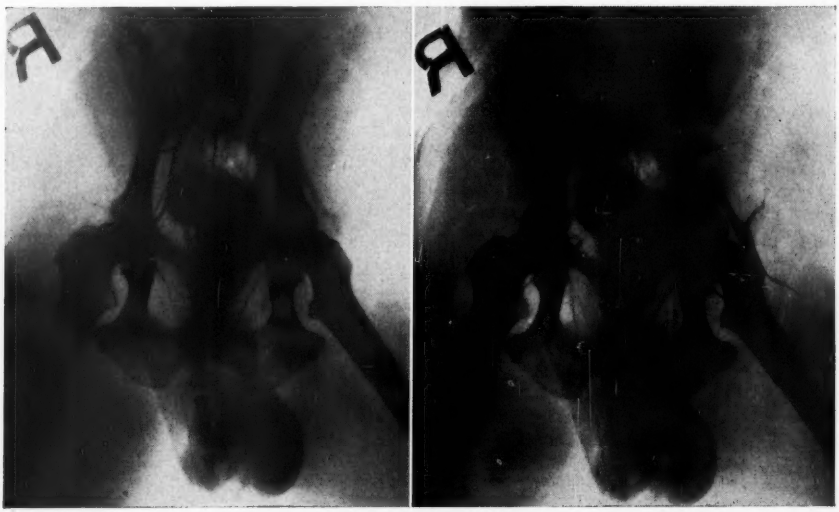


Fig. 9.—Pulmonary arteries and veins clearly visible after injection of contrast fluid into the right heart during increased intrabronchial pressure to 60 cm. water.



A. *B.*

Fig. 10.—Contrast medium remains in pelvic vessels as long as intrabronchial pressure is raised to 60 cm. water. Between *A* and *B* there is a period of 12 seconds.

movements of the heart and vessels produce much clearer contours. The diameter of the aorta is reduced to approximately two-thirds of its normal size. The left ventricle gives a clear image when filled. The aortic valves can be clearly identified.

Filling of the coronary arteries is easily performed even from the aortic arch. The time factor is of little interest as the contrast remained unchanged for at least 4 seconds (Fig. 7).

With the catheter placed in the right auricle or right ventricle, excellent visualization of the right heart, outflow tract, and pulmonary arteries was obtained (Fig. 8). Visibility was maintained in the lungs during elevation of the intratracheal pressure for periods up to 5 seconds with a preceding injection time of equal duration. In some instances, both pulmonary arteries and veins were visualized simultaneously with a contrast dose of 25 c.c. of 45 per cent concentration (Fig. 9). This proves again that it is not the compression of the pulmonary capillaries which is the most important factor in slowing down of the blood stream when the intratracheal pressure is increased to 60 cm. water. The use of this method for aortography of the abdominal aorta has not yet been studied extensively. The possibility of obtaining peripheral arteriograms by injection of a small dose of contrast medium of low concentration seems attractive. Sharper contours should simplify the diagnostic possibilities of vascular lesions. Serial exposures of dubious lesions are quite possible as the contrast remains visible for prolonged periods (Fig. 10).

CONCLUSION

The roentgenologic study of contrast fluid in the heart and great vessels confirms the views of Weber who stated that elevation of the intratracheal pressure caused a slowing down of the bloodstream through the heart by compression of the right heart and the venae cavae. From a practical point of view, the advantages of our new roentgenographic method seem considerable not only in the experiments described, but possibly also in clinical angiocardiography.

The advantages for diagnostic angiocardiography may be summed up as follows: A better insight into the pathology of the coronary arteries may be obtained, with the possible development of surgical therapy of chronic disorders. The roentgenographic approach to congenital abnormalities of the heart may be improved. The absence of, or change in, the difference in pressure between left and right heart may result in a direct visualization of the shunt, intra- or extracardial, after injection of the contrast medium. Abnormalities in the region of the aortic arch may be depicted more clearly. Pneumangiocardiography and arteriography of special organs can be performed more easily and with a minimum of danger.

The clinical application of our method of roentgenography will be described in detail later.

Dawson expressed the opinion that it would be regrettable if the vast amount of experimentation carried out on the work of Valsalva proved fruitless and could not be utilized to human advantage.

We think that this experimental study, by means of its clinical application, will provide clearly and simply information which will be of great value in medicine today.

SUMMARY

A new method for angiocardiography is described. Use was made of slowing of the blood stream through the heart and the fall in blood pressure occurring after increased intrabronchial pressure to values between 40 and 60 cm. of water. It was shown that this slowing down of the blood flow through the heart was primarily caused by compression of the right heart and both venae cavae. Pressure recordings made during this procedure showed that there is no danger of congestion of the right heart. Experiments performed in dogs show that clear visualization of coronary arteries, heart chambers, aortic arch, and pulmonary vessels is possible with a minimum of contrast medium of low iodine content, injected under low pressure.

We are indebted to Mrs. D. M. E. Vermeulen-Cranch, F.F.A.R.C.S., and J. van Leeuwen, M.D., from the Department of Anaesthesiology, R. Lopes Cardozo, M.D., and Miss E. van Buuren from the Department of Radiology for their technical assistance.

REFERENCES

Brookhart, J. M., and Boyd, T. E.: Local Differences in Intrathoracic Pressure and Their Relation to Cardiac Filling in Dog, Am. J. Physiol. **148:** 434, 1947.

Dawson, P. M.: Historical Sketch of Valsalva Experiment, Bull. Hist. Med. **14:** 295, 1943.

Einbrodt: Über den Einfluss der Atembewegungen auf Herzschlag und Blutdruck, Sitzungsber. d. Kaiser. Akad. d. Wissensch. Math.-Nat. Cl. **40:** 361, 1860.

Guglielmo, L. D., and Guttadauro, M.: A Roentgenographic Study of the Coronary Arteries in the Living, Acta radiol., supp. 98, 1952.

Hamilton, W. F., Woodbury, R. A., and Harper, H. T.: Arterial Cerebrospinal and Venous Pressures in Man During Cough and Strain, Am. J. Physiol. **141:** 42, 1944.

Helmsworth, J. A., McGuire, J., Felson, B., and Scott, R. C.: Visualization of Coronary Arteries During Life, Circulation **3:** 282, 1951.

Holt, J. P.: Effect of Positive and Negative Intrathoracic Pressure on Cardiac Output and Venous Pressure in Dog, Am. J. Physiol. **142:** 594, 1947.

Hoyos, J. M., and Gomez del Campo, C.: Direct Thoracic Aortography and Arteriography of the Coronary Vessels, Cardiologia **23:** 251, 1953.

Humphreys, G. H., Moore, R. L., Maier, H. C., and Apgar, V.: Studies of the Cardiac Output of Anesthetized Dogs During Continuous and Intermittent Inflation of the Lungs, J. THORACIC SURG. **7:** 438, 1937.

Humphreys, G. H., Moore, R. L., and Barkley, H.: Studies of the Jugular, Carotid, and Pulmonary Pressures of Anesthetized Dogs During Positive Inflation of the Lungs, J. THORACIC SURG. **8:** 553, 1938. Studies on Jugular Pressure of Anesthetized Dogs During Positive Inflation of Lungs Before and After Pneumonectomy, Surgery **10:** 21, 1941.

Jönsson, G., Broden, B., and Karnell, J.: Thoracic Aortography With Special Reference to Its Value in Patent Ductus Arteriosus and Coarctation of the Aorta, Acta radiol. supp. 89, 1951.

Mautz, T. R.: Medical Physics, Glaser, Chicago, 1944.

Pearl, F.: Coronary Arteriography in Intact Animal, J. Internat. Coll. Surgeons **18:** 40, 1952.

Radner, S.: An Attempt at the Roentgenologic Visualization of Coronary Blood Vessels in Man, Acta radiol. **26:** 497, 1945. Thoracical Aortography by Catheterization of the Radial Artery, Acta radiol. **29:** 178, 1948.

Saklad, M.: Pressure Breathing in Surgery, J. THORACIC SURG. **28:** 31, 1948.

Sauerbruch, F.: Zur Pathologie des offenen Pneumothorax und die Grundlagen meines Verfahrens zu seiner Ausschaltung, Mitt. a. d. Grenzgeb. Med. u. Chir. **13:** 399, 1904.

Valsalva: cited by Dawson from Morgagni.

Weber, E. F.: Über ein Verfahren den Kreislauf des Blutes und die Funktion des Herzens willkürlich zu unterbrechen, Berichte über die Verhandlungen der königl.-med. Gesellschaft der Wissenschaft in Leipzig, p. 29, 1850.

Wickbom, I.: Thoracic Aortography After Direct Puncture of the Aorta from the Jugulum, Acta radiol. **38:** 343, 1952.

Wiggers, C. J.: Physiology in Health and Disease, Philadelphia, 1949, Lea and Febiger.

THROMBOSIS OF INTERNAL JUGULAR VEIN SECONDARY TO INTRATHORACIC DISEASE

ANDREA CIUTI, M.D., FLORENCE, ITALY, AND EDWARD F. SKINNER, M.D., MEMPHIS, TENN.

IN THE course of performing some one hundred and fifty supraclavicular biopsies for various chest diseases, we have encountered several cases with complete thrombosis of the internal jugular vein secondary to the intrathoracic disease. We would like to give two of these cases in some detail in this presentation, as there is little mention of this complication in the literature.

There are, however, numerous instances reported in which thrombosis of the internal jugular vein occurred secondary to some disease in the lateral sinus or followed operations about the nose and throat.

When a surgeon, doing a routine supraclavicular biopsy, encounters a thrombosed internal jugular vein, a problem is raised. If the condition is not recognized immediately, an attempt might be made to remove this mass on the false assumption that it was a mass of matted lymph nodes. This could have fatal results. We have used a small needle to aspirate the thrombosed jugular vein when it is exposed at surgery but have been unable to obtain enough material by this means for a Papanicolaou stain. We have considered using a needle with a larger bore for the same purpose and this probably could be done with safety; however, so far we have not tried this.

The cases reported by Dr. Scheshter in his paper entitled "The Superior Venacava Syndrome," although not identical with those we are reporting, are similar enough to be of interest. In searching the literature, he found 274 cases of superior vena cava syndrome which were confirmed sufficiently to be of statistical importance. Approximately 75 per cent of all those reported cases were caused either by primary intrathoracic neoplasms, aortic aneurysms, or lymphomas. The cases due to aortic aneurysm have decreased in number in the recent literature. Dr. Scheshter reported twenty-two cases in his series from New Orleans. He stated that almost all cases of superior vena caval obstruction by intrathoracic malignancies were caused by direct invasion of the venous wall by tumor tissue. He found an incidence of 11 per cent involvement and obstruction of the superior vena cava in primary carcinoma of the lung. He concluded that superior vena caval obstruction is not nearly as rare as was formerly believed.

CASE REPORTS

CASE 1.—Mrs. E. V. was a white widow, 68 years of age. This patient was first admitted to the Baptist Memorial Hospital, Memphis, Tenn., on Aug. 8, 1953. For the preceding month, she had noted increased dyspnea, weakness, and a dry, hacking cough. She was unable to lie on the left side because of shortness of breath. She stated she had had "flu" in the spring and had not felt well since that time. During the week preceding admission, there

Received for publication Dec. 14, 1954.

had been some swollen glands in the neck. Anorexia and some weight loss were also noted. There were no known tuberculosis contacts and she had no hemoptysis, fever, chills, or night sweats. There were no gastrointestinal, genitourinary, or gynecological symptoms.

Physical examination showed the patient to be an elderly white woman, orthopneic but not cyanotic. There was a diffuse tenderness over the left side of the neck but no definite nodes were palpable. Breath sounds were absent and coarse râles were heard above the right leaf of the diaphragm, with some flatness to percussion in this area, and with scattered fine râles over the left lung. There were noted a diffuse tenderness of the abdomen and a questionable liver enlargement. There was little change from the condition shown by a previous series of films made at the Houston Hospital, Houston, Miss., on July 28, 1953, through Aug. 1, 1953. All the films demonstrated an irregular collection of fluid just above the right diaphragm with questionable enlargement of the right hilar shadow. The admission diagnosis was "right pleural effusion of undetermined origin."

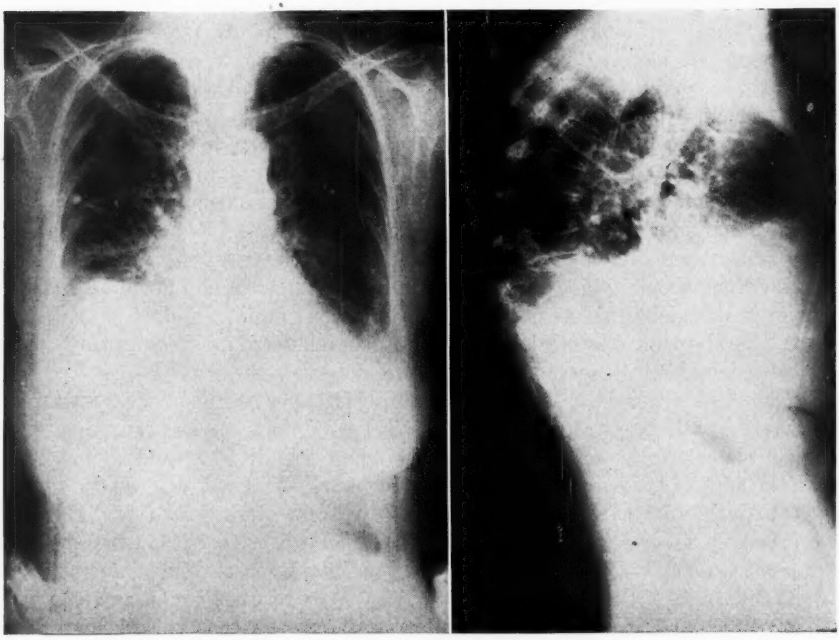


Fig. 1. Fig. 2.

Fig. 1.—Case 1. Mrs. E. V., Aug. 18, 1953. This film demonstrates a small amount of fluid in each pleural space, with questionable enlargement of the right hilar shadow and some congestive changes in both lungs.

Fig. 2.—Case 1. Mrs. E. V., Aug. 18, 1953. Right lateral film. A marked senile kyphosis is noted with some pulmonary emphysema and again the small pleural effusion and passive congestive changes in the lung.

Examinations of sputum and pleural fluid were negative for tumor cells. Indirect laryngoscopy and bronchoscopy were essentially normal except for slight edema of the mucosa of the right middle and lower lobe orifices, but no secretions were present on either side. The patient was slightly orthopneic before bronchoscopy so the procedure was done in the sitting position. The bronchoscopic sputum likewise was negative for tumor cells.

A complete blood count was within the range of normal limits and the urinalysis was normal. The VDRL test was negative.

On Aug. 10, 1953, a left supraclavicular biopsy was performed under 1 per cent Novocain infiltration anesthesia. A two-inch incision was made over the sternocleidomastoid muscle on the left horizontally, midway between the mandible and the clavicle. By blunt dissection, the mass underneath the sternocleidomastoid muscle was explored and there was noted a complete thrombosis of the internal jugular vein. The vein was larger than normal and very succulent but firm. It was aspirated with a small gauge needle but no free blood could be found in it. By following the vein downward, it was apparent that the thrombosis extended to the junction of the internal jugular and subclavian veins. We considered ligating the vein to prevent emboli but this was not done as we feared it might pinch off another blood clot. It was suggested that, if ligation were to be done, it probably should be performed at the lowest portion of the internal jugular vein, with the patient under general anesthesia. No biopsy was taken. The incision was closed with interrupted subcuticular sutures of No. 000 chromic catgut. The postoperative condition was good.

Dr. W. W. Taylor saw this patient in consultation with us and the final diagnosis was congestive heart failure with complete thrombosis of the internal jugular vein. She was put on appropriate cardiac medical therapy. Inasmuch as she had had some thrombophlebitis in the legs previously, we considered her to have a migratory thrombophlebitis. If any future embolic episodes occurred, it was suggested that anticoagulant therapy be started. The patient was discharged from the hospital on Aug. 18, 1953, somewhat improved clinically.

Posteroanterior and lateral chest films made Aug. 18, 1953, showed a bilateral pleural effusion. The heart was obscured by the pleural effusion to a great extent and therefore the cardiac size could not be accurately determined. There was considerable kyphosis of the dorsal spine. There were some calcific plaques in the aortic arch. Films made a week later showed a decrease in the pleural effusion, bilaterally, but congestive changes were noted in both lung fields.

Comment.—This patient had a complete thrombosis of the internal jugular vein, with congestive heart failure, and a migratory type of thrombophlebitis.

CASE 2.—Mr. J. C. was a white man, 61 years of age. This patient was seen in consultation with Dr. Arthur W. Green at St. Joseph Hospital, Memphis, Tenn., on Nov. 10, 1953. He gave a history of an injury to the back and right shoulder, due to a fall sustained six or seven years previously. During the past several years, he had noted a drawing sensation in the neck on the right side. Two or three years before the neck had become sore and stiff but eventually this had disappeared almost completely. Two weeks prior to admission to the hospital, the neck condition had flared up again with swelling and extreme tenderness. He had noted some earache. He had a dry, hacking cough with very little sputum. His weight was fairly stationary at 155 pounds. He stated he had had headache all the preceding summer and some weakness in the legs also. He had had several spells during which he felt faint but had never completely lost consciousness. His customers, however, had remarked on how poorly he looked at such times. Two weeks before admission to the hospital, he had noted a rattling in his throat. He reported having colds of a persistent nature every winter.

Physical examination revealed a well-developed, well-nourished white man, who did not appear acutely ill. There was a diffuse mild tenderness and slight spasm over the right sternocleidomastoid muscle. No well-defined mass was palpated. No supraclavicular nodes were demonstrated. The remainder of the physical examination was essentially negative except for a slight watchglass fingernail tendency.

X-ray films of the chest showed a ground glass appearance in the upper portion of the lung fields, which was more extensive on the right side. There appeared to be a tumor, in the right hilar area beneath the mediastinal pleura, which was homogeneous in density with the mediastinal shadow. On the lateral film this tumor was midway between the anterior and posterior walls. Our first impression was that this was a "mediastinal tumor of undetermined origin."

On Nov. 11, 1953, a right supraclavicular biopsy was performed, using 1 per cent Novocain infiltration anesthesia. A portion of the sternocleidomastoid muscle was removed

for biopsy. No *enlarged* lymph nodes were found but two or three nodes were removed for study. The internal jugular vein was identified and was found to be completely thrombosed, and slightly enlarged. The wound was closed and a cyst on the back, which contained some calcification, was then removed.

The pathologic report was "sections of the muscles show well developed bundles of striated muscle. There is a minimal focal, chronic inflammatory cell reaction. The blood vessels are not remarkable. There is no evidence of collagen disease. Cervical nodes show no tumor."

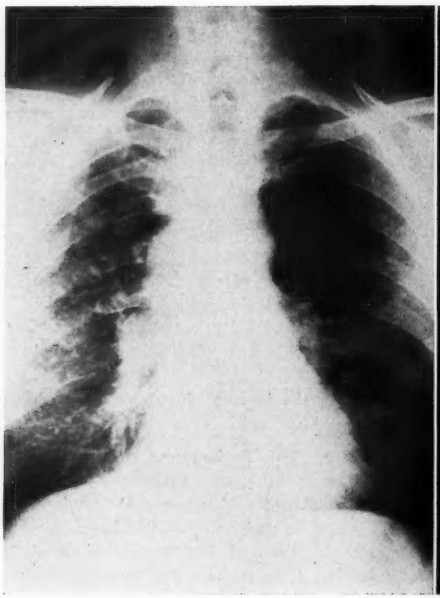


Fig. 3.

Fig. 4.

Fig. 3.—Case 2. Mr. J. C., Nov. 9, 1953. There appears to be a tumor in the right hilar area beneath the mediastinal pleura. This shadow is homogenous in density with the mediastinal shadow. There is a ground-glass appearance over the upper portion of the right lung field and to a lesser extent over the upper half on the left.

Fig. 4.—Case 2. Mr. J. C., Nov. 10, 1953. Right lateral film demonstrates the tumor to be located midway between the anterior and posterior chest wall in the hilar area. There is also some infiltration in the right middle lobe area.

Bronchoscopy and an indirect laryngoscopy were performed on Dec. 15, 1953. There was considerable purulent sputum bilaterally, chiefly on the right side. There was approximately a 25 per cent narrowing of the right main bronchial orifice with some redness in this location. The remainder of the examination was essentially negative. Secretions from the right main bronchus were negative for tumor cells. Several expectorated specimens of sputum were negative also for tumor cells. On cultures, the sputum contained no tubercle bacilli or fungi, but rare gram-positive cocci were obtained.

The electrocardiogram was normal, as was the urinalysis. The blood albumin-globulin ratio was normal. The hemoglobin was 10.5 Gm., red blood count 4.5 million, white count 11,850. A sternal puncture was done Dec. 29, 1953, and resulting paraffin sections were negative for Hodgkin's disease. Although no definite pathologic diagnosis had been established, clinically, we felt that the patient had a bronchiogenic carcinoma with complete thrombosis of the right internal jugular vein. He was given 40 mg. of Mustargen intravenously in divided doses and discharged from the hospital. He apparently did well for

two months. He was next heard from on Feb. 20, 1954, at which time he was admitted to the Kennedy Veterans Hospital in Memphis. On admission, he was in extremis and the admitting diagnosis was terminal bronchiogenic carcinoma of the lung with superior vena caval obstructive syndrome. The history obtained from the relatives was that the patient had tolerated the chest and neck pain much better and had improved clinically following the nitrogen mustard therapy until a few days before admission to Kennedy Veterans Hospital. Three weeks prior to admission to that hospital, he had developed a bilateral thrombophlebitis of the lower extremities which was still present on the right side at the time of admission. Three days prior to admission he developed hemoptysis which had become more copious on the day of admission.

On physical examination, he was moribund, with pulse of 120, blood pressure 97/60, temperature 97° F. The skin was of a lemon color. There was some residual edema of the orbital tissues over the face, upper thorax, and upper extremities, but no cyanosis. Pedal edema was present. There was subcutaneous edema of the thorax, upper extremities, face, and neck. Impaired tactile fremitus was noted over the right base with breath sounds absent in that location. Above this area was a definite expiratory wheeze. Râles were present in both bases. The heart tones were distant. The liver was enlarged, four fingerbreadths below the costal margin. No lymphadenopathy was present. The abdomen was essentially negative. The chest film showed considerable mediastinal lymphadenopathy with a pleural effusion at the right base and scattered parenchymal infiltrations compatible with an extensive bronchiogenic carcinoma. The white count was 19,800, with 10.6 Gm. of hemoglobin, red blood count 3.9 million, and the urinalysis was normal. The patient died on Feb. 22, 1954, at 2:20 P.M. and an autopsy was performed. The pertinent findings from this examination were as follows:

Jugular Vein and Thoracic Duct.—Sections from the thrombosed area in the jugular vein and from the wall of the jugular vein high up showed only thrombus material occluding this structure. The thrombus material was attached to the wall and had partially recanalized. Most of the thrombus was organized. As one came down toward the junction with the innominate vein, however, definite tumor appeared in the vein and blocked the entire opening of the thoracic duct into the jugular vein. The thoracic duct was greatly dilated and completely filled with tumor.

The Final Anatomical Diagnosis.—1. Bronchiogenic carcinoma, right, with metastases to the left lung, adrenals, kidneys, and left rectus muscle, and direct extension to the mediastinum with involvement of the superior vena cava and the thoracic duct. Metastases also were present in the heart. 2. Thrombosed internal jugular vein, secondary to the tumor. There were metastases also in the jugular vein. 3. Verrucas vegetations were present in the tricuspid valve, and the right ventricular cavity.

Comment.—This second case was a bronchiogenic carcinoma which had extended, causing complete thrombosis of the internal jugular vein.

CONCLUSIONS

Intrathoracic disease can cause thrombosis of the internal jugular vein, the most common of these diseases being bronchiogenic carcinoma. To the surgeon, this possibility is very important and he should keep it in mind whenever he is performing a supraclavicular biopsy. Two illustrative cases are included.

REFERENCES

1. Bjarnason, O.: Bilateral Thrombosis of Jugular Vein, Nord. med. 32: 2514-2515, 1946.
2. Dargent, M., Guinet, P., and Gaillard, J.: Malignant Internal Jugular Vein Obliteration Due to Cancer of Thyroid, Lyon chir. 43: 443-454, 1948.
3. Flett, R. L.: Jugular Thrombosis After Tonsillitis, Brit. M. J. 2: 223-225, 1941.
4. Loebell, H.: Unusual Cerebral Complications in Otogenous Sinus and Jugular Vein Thrombosis, Ztschr. Laryng. Rhin. Otol. 29: 175-183, 1950.
5. Scheshter, M. Murray: The Superior Venacava Syndrome, Am. J. M. Sc. 227: 46-56, 1954.
6. Smith, A. B.: Otogenous Thrombophlebitis of Lateral Sinus and Jugular Bulb, J. Laryng. & Otol. 64: 12-16, 1950.

A METHOD FOR THE SURGICAL CORRECTION OF MITRAL INSUFFICIENCY

ROGER BENICHOUX, M.D.,* AND PIERRE CHALNOT, M.D.**
NANCY, FRANCE

MITRAL insufficiency remains one of the most serious sequelae of acute rheumatic disease. Its surgical treatment is far from being as good as that for mitral stenosis.

PATHOLOGY AND PHYSIOPATHOLOGY OF MITRAL INSUFFICIENCY

The pathology must be the guide for a surgical correction of mitral insufficiency. All parts of the mitral valves are involved by the rheumatic inflammatory disease.[1] The free border of the valves is shortened and deformed, and their attached edge is thickened and immobilized by a symphysis, which joins the inferior surface of the valve to the adjacent part of the ventricle. The chordae tendineae are thickened and retracted. Their insertions are lengthened due to the dilatation of the ventricles. This results in a reduction of the effective surface of the valves. The volume of the left auricle is soon markedly raised. The regurgitation is then further aggravated by the dilatation of the atrioventricular ring.

We do not consider it necessary to detail the changes associated with the mitral narrowing or the varying stages of the anatomical evolution. They can be deduced from the type of lesions just described. It seems to us more important to be able to recognize the key lesion of this serious condition. To arrive at this, we should recall some physiological ideas on the contraction of the ventricle and closing of the valves. It is, in fact, impossible to dissociate these two factors. The studies of Haygraft,[2] Lundin,[3] Rushmer,[4] and Thal[5] on normal ventricular contraction are of the greatest value. Rushmer has employed a method of metal markers enclosed in the ventricular wall and in the interventricular septum. The cinefluorography of the heart thus made has allowed him to register and analyze all its movements. The range of movements of the metal points in the ventricles is different, but the direction is constant. They displace toward the apex, thus lowering the mitral ring, and also in an oblique direction toward the base and toward the interventricular septum. At the same time, the mitral ring contracts. Schemas of the exact valvular apparatus have been offered by Harken,[10] Bailey,[6] and Brock.[7] Although every cardiac surgeon can get an idea of its function by introducing a finger into the auricle, one can consider the film of Hurwitt[8] as being the greatest contribution to the physiological study of the mitral valves. In his experiment, the left ventricle of an animal was dried by means of the pump of an artificial heart-lung apparatus. The myocardium contracted and the valves continued to

Received for publication Jan. 14, 1955.
*Assistant Surgeon, Hôpital Central, Nancy, France.
**Professor of Clinical Surgery, Hôpital Central, Nancy, France.

function normally as the coronary arteries were normally perfused. Thus, through the open auricle or through the open ventricle it was easy to follow the movements. At systole, the valves join together like two half parachutes, to use the expression of Harken. For the moment, it is of little importance

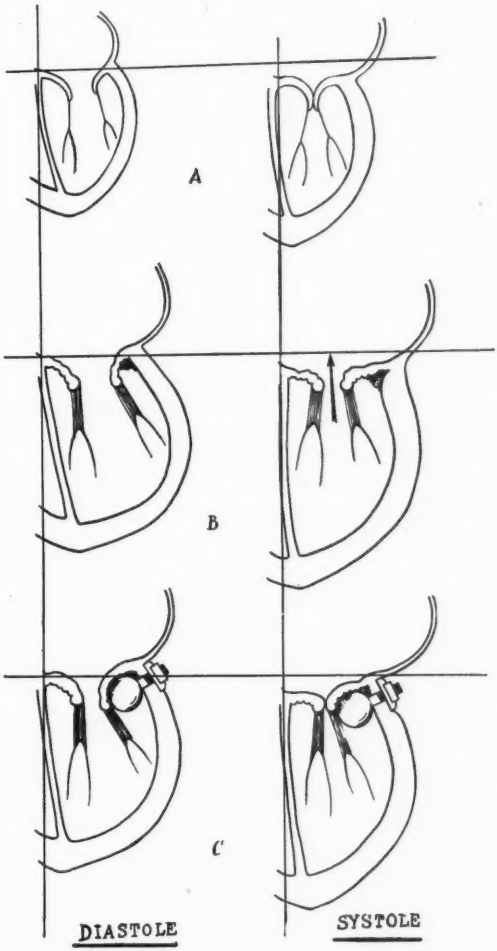


Fig. 1.—*A*, Normal mitral valves, *B*, Mitral regurgitation, *C*, Mitral regurgitation corrected by our prosthesis. Note the lowering of the mitral ring and the ventricular contraction during the systole.

that they cover each other or that they face each other under the systolic flow of blood. This unfolding of the valves is further increased by the lowering of the mitral ring and by the ventricular contraction during the systole. The chordae tendineae slacken at this moment so as to contract at the diastole. The

regurgitation is thus a defect in the coming together of the two valves of the valvular parachutes. The valves and the chordae tendineae are shrunken, the mitral ring widened, and the left ventricle augmented in volume (Fig. 1).

THE GENERAL CONDITIONS OF A SURGICAL CORRECTION

Any surgical treatment of mitral insufficiency is a question of choosing among several possibilities: (a) a direct attack on the insufficient valves involving an actual valvuloplasty (Bailey[9]), (b) the placing of a prosthesis to fill in the gap in the mitral orifice (Harken,[10] our method[12-14]), and (c) a search for a means of shortening the mitral ring (Glover[11]).

But above all, any treatment of mitral insufficiency must obey the following rules:

1. The operation must be simple and speedy. In a condition as grave as this, the patient could not endure long and complicated techniques. This eliminates, at least for the present, surgery with the open heart using the artificial heart-lung. Surgery by means of hypothermia allows only a few minutes of work, which is insufficient for lesions so complex.

2. The operation must not cause thrombosis. Rheumatic endocarditis can of itself be a cause of thrombosis and emboli. But the slightest foreign body in the heart, above all, if it is in the midst of the blood flow, can induce it. In particular, one must absolutely avoid any foreign body in the left auricle which is the usual site of thrombosis. The material of the foreign body is also important. Fragments of tendon, strips of pericardium, segments of turned back vein, and plastic prostheses have been used inside the left ventricle. We think that the plastic prostheses are the least likely to produce thrombosis. But the perfect fixation of the foreign body to the myocardium seems to be the most important factor of tolerance. Take, for example, a prosthesis that we will describe further on. When this prosthesis is not completely bound to the myocardium, the contraction of the ventricle and the blood flow communicate to it a rhythmical movement comparable to that of the movement of a bell. This churning of the blood causes a thrombosis.

3. The foreign body must be sufficiently fixed so as not to embolize. The prosthesis, itself, must be solid and in one piece, to avoid all risk of breakage.

4. Last, it is necessary that by its volume, the element of repair, thread, or prosthesis should not diminish in any way the volume of the left ventricle.

Having defined the conditions for an operation which will not be dangerous, we are obviously limited as how to meet the demands of an efficient correction for mitral insufficiency. The rigidity and insufficiency of the mitral opening are due to the lessening of the surface and mobility of the valves. The retraction of the chordae tendineae and the enlargement of the muscular mitral ring make the wide-mouthed orifice still larger. Will it be sufficient to bring together the two borders of the valves to do away with the regurgitation as Bailey practices it? Ought one to prefer the tightening of the muscular ring as Glover suggests? What are the reasons for choosing an intracardiac prosthesis to make up for the valvular insufficiency, and how is one to choose between all those that have been tried?

Experiments on animals should be able to prove the efficiency of one of these operations. Unfortunately, any experimental mitral insufficiency in animals can compare only roughly with that in human beings. In a dog, one can produce the latter only by means of a serious valvular injury, which is exceptional in the human being. The rupture of a valve is severe and often fatal, due to the sudden hemodynamic disturbance which it produces. Nor is it accompanied by any of the valvular and tendinous retractions which one usually finds in rheumatic endocarditis. Thus animal experiments are inexact and very difficult to evaluate for the survival of the dog is rare. Therefore, the efficiency of any surgical treatment for mitral insufficiency must be judged by operations on man. Unfortunately, it is difficult to arrive at a conclusion at the present time. The statistics already published are incomplete and are too cautious about the causes of death and about the condition of the patients who have survived the operation.

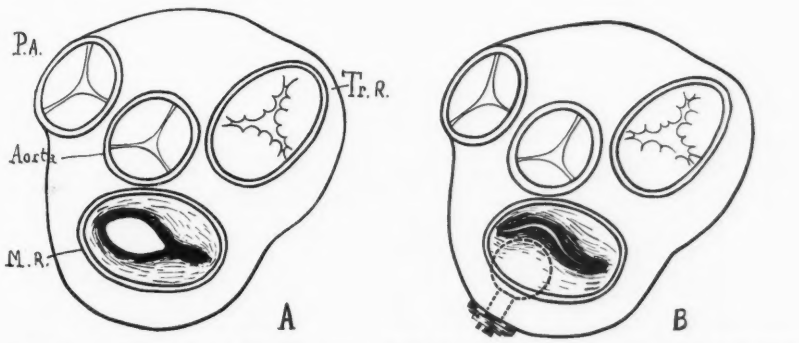


Fig. 2.—A view into the atrioventricular rings in a heart in which the atria have been removed. *P.A.*, pulmonary artery and valves; *T.R.*, tricuspid ring; *M.R.*, mitral ring. *A*, Shows a combined mitral stenosis and insufficiency. *B*, Shows commissurotomy and correction of the insufficiency by our prosthesis.

THE OPERATION OF GORDON MURRAY

Our research on the surgical treatment of mitral insufficiency started in 1951. At first, we experimented with a variation of the method of Gordon Murray, using a transventricular pericardium flap.

Our results confirmed those of former research workers. It consisted of a benign operation well withstood. After opening the thorax and pericardium, one cuts from the latter a pedunculated strip. It is then sewed in a finger shape, 5 cm. by 1 cm. A Reverdin curved needle is used to cross the left ventricle perpendicularly, and pick up the end of the pericardial flap and introduce it into the ventricular cavity. One can either attach this end to the opposite ventricular wall, or leave it free.

To be efficient, this strip, theoretically, should be set on an axis perpendicular to that of the normal mitral orifice. But for obvious anatomical reasons, already detailed by Brock and shown on a schema (Fig. 2), the strip can be only parallel to the axis of the mitral opening. In fact, this pericardial strip

always scleroses and thus loses any value. We have been able to verify this on a group of three dogs, which when sacrificed, 75, 105 days, and more than 1 year after the operations, all showed the same sclerosis of the flap. Therefore, we planned a prosthetic intracardial piece to be fixed against the myocardium, under the posterolateral valve.

DESCRIPTION OF OUR METHOD

Since 1951, we have been searching for the ideal form for this prosthesis.[12-14] We have used different types of lens and, also, sword-shaped pieces in plastic. Finally, we have chosen spherical balls, perfectly smooth. At first, the ball was fastened by a steel wire, passed through the ball, whose two ends, after passing through the myocardium, could be drawn taut and tied on the outside. But experience proved that these wires broke quickly; therefore, we use a rigid type (Fig. 3). It is composed of a sphere, whose diameter depends on the size of the mitral ring and the heart volume. The sphere has on one side of it a shank threaded along all its circumference, except for 2 symmetrical flat

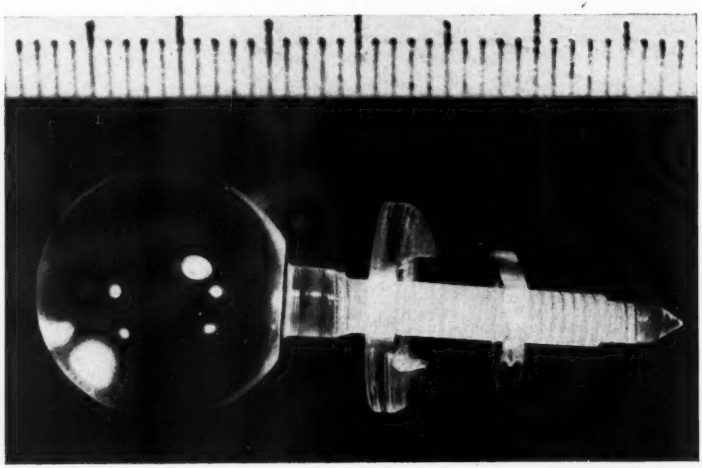


Fig. 3.—The ball we are using. Note in the middle of the figure the counterscrew which glides along the shank, and at the right end, the screw which is fastened on the shank.

sides. These 2 flat sides act as a surface for a counterscrew which cannot turn, to glide along the shank. Another screw is fastened on the shank, this screw fits into an opening cut out of the outer side of the counterscrew. As soon as the screw is placed in the counterscrew, it is firmly held by a lock-nut principle. The balls we have used had a diameter of 10 to 15 mm. We have used shanks 25 mm. long, ending in an eyelet hole, through which a draw thread can be put.

Access to the heart and more especially to the left ventricle is made by an anterolateral thoracotomy as low as the level of the seventh intercostal

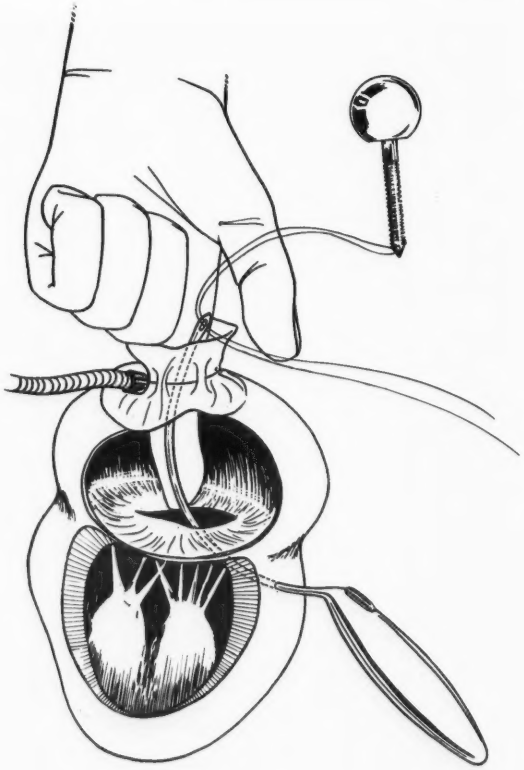


Fig. 4.

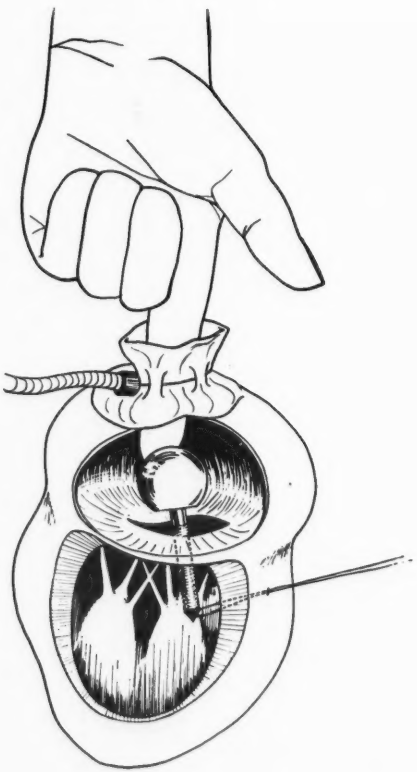


Fig. 5.

Fig. 6.

Fig. 4.—The index finger introduced in the auricle conducts a blunt-ended Reverdin's needle.
Fig. 5.—The index finger pushes the ball toward the ventricle.
Fig. 6.—The ball in place. Note its position under the posterolateral valve and the fixation by the lock-nut system.

space. One must be able to approach the posterolateral surface of the left ventricle which is adjacent to the diaphragm. The pericardium is opened by a longitudinal incision, parallel to the phrenic nerve. Opening of the auricle and mitral exploration are done in the usual manner. The latter, however, is the guide in the choice of the size of the ball and of its position under the posterolateral valve. With the index finger always in the auricle, a blunt-ended Reverdin's needle is introduced into the ventricle (Fig. 4). The point of approach must be clearly known; it is situated immediately behind the circumflex artery, a branch of the auriculoventricular artery, 2 fingerbreadths under the auriculoventricular groove, in other words, in the part most posterior to the ventricle. The needle pierces the ventricle rapidly and then enters the atrium. It comes out along the index finger. One quickly passes a thread which secures the ball by the end of its shank. The needle is then withdrawn through the myocardium. The index finger is then removed from the auricle, which is clamped. Following this, it is easy with a little experience to pass the ball quickly into the auricle, without any appreciable loss of blood. The finger follows the ball which, pushed from one side, drawn by the transmyocardial thread from the other, is to be fixed in the required corner (Fig. 5). Then all that is necessary is to slide the counterscrew, to fasten the screw, and to cut the obtruding part of the shaft (Fig. 6). After another verification by the mitral finger, the auricle, the pericardium, and the thorax can be closed. The operation is simple and does not entail much loss of blood. It should last not more than one and one-half hours.

MATERIAL AND RESULTS

Thirty-seven healthy, adult mongrel dogs weighing from 10 to 30 kilograms were used for this experiment.

In a first group, we operated on five dogs using different types of prostheses. On one dog, a ball fixed to the myocardium by a nylon hammock rapidly embolized. To lessen mobility of the ball, we put a steel wire through it. The two extremities of the wire after passing into the myocardium were tied outside on a small plastic button. On other dogs, a spherical ball was used three times and a sword-shaped piece just once. After these operations, three dogs died within 24 hours. Another died of endocarditis on the twenty-fourth day as a result of the beating of the insufficiently fixed ball. Last, a fifth dog had to be sacrificed on the fortieth day. The ball had been secured by two wires and only one was found intact. We, also, found that the prosthesis was firmly enclosed under the posteroexternal valve and covered by a sheet of fibrous tissue continuous with the endocardium around it.

We gave up this method of maintaining the prosthesis because: (a) the fixation was insufficient, (b) the fixing wires broke almost every time.

In our second group, we used the Plexiglass ball with threaded shank. The operative technique used was that set out and described at the beginning of this paper.

In twenty-two operations on dogs:

10 died within 12 days following the operation
1 died on the thirtieth day
6 were sacrificed between 2 to 3 months after
3 were sacrificed between 5 to nine months after
1 was sacrificed after 22 months
1 is living after more than 23 months

The causes of death were:

2 due to pleural empyema
3 due to operative hemorrhage or anoxemia, and
6 due to thrombosis and emboli, resulting from malposition of the ball

The eleven dogs that died were among the first thirteen operated on in this group, while we were looking for a good technique. The most frequent cause of death was embolus, coming from the thrombosed areas around the prosthesis. In all these cases, the prosthesis had been incorrectly placed; in three dogs, the ball was found to be in the atrium, its shaft piercing the small valve, and in three other dogs the screw had been insufficiently tightened and the ball was loose in the ventricle. We think that these malpositions were the cause of thrombosis and emboli. Since we have succeeded in placing and fixing the balls correctly, these complications have disappeared.

The study of the eleven surviving animals has shown an excellent tolerance. After the postoperative period they have lived normal lives among the others in a big kennel. All the animals, save one, were sacrificed at different periods between 2 and 22 months. The animal examined 22 months after the operation was one which, 8 months after the operation, had whelped a big litter. One dog, 23 months afterward, is living and in good health.

Our examinations have shown that the heart has never increased in size. Externally, there was no evidence of the operation, except for a slight pericarditis, thickened a little at the point of the lock-nut. The cardiac cavities have never revealed signs of thrombosis. The prosthesis was in good position under the posterolateral valve. Each time it was seen to be covered by tissue which, to the naked eye, was a complete continuation of the adjacent endocardium (Fig. 7). Microscopic examination showed this covering to have all the histological characteristics of the endocardium (Fig. 8).

Our third group consisted of ten dogs. The aim was to create a mitral insufficiency and then to correct it by means of our prosthesis. We showed earlier that any such insufficiency produced artificially can simulate only poorly the patterns of that found in human beings, while, on the other hand, it increases hemodynamic disturbances.

We operated in the following manner. By means of two polythene catheters introduced into a left pulmonary vein, the pressures of the auricle and left ventricle were registered simultaneously. One of these catheters led to the atrium and the other to the left ventricle.

It is more difficult than one believes to destroy a mitral valve in a normal animal. In any case, the finger can do little damage to the cords and valves.

Fig. 7.—The heart of a dog sacrificed twenty months after the operation. The prosthesis is covered by a tissue in complete continuation with the adjacent endocardium.

Fig. 8.—Microscopic section of the tissue covering the prosthesis twenty months after operation (same animal as in Fig. 7). *A*, The cardiac lumen. All the structure of an endocardium is reproduced.

We devised a special valvulotome in the form of a scythe. The index finger holding this valvulotome was introduced into the left auricle, and cut the insertions of the posterolateral valve in whole or in part. It is difficult to proportion the lesions. One can estimate them only after observing the

hemodynamic alterations. At this point of the operation, hemostasis of the auricle is harder to accomplish. The blood jet is markedly more forcible. The pressure in the auricle is considerably raised and lowered in the ventricle. Mitral regurgitation is evident and, if it is not immediately corrected, death is almost instantaneous.

When our prosthesis is fixed, the clinical and hemodynamic signs disappear immediately. Auricular hemostasis becomes easier and the force of the pulsations of the auricle lessens. Left auricular pressure, though considerably lowered, does not reach the normal preoperative level registered. This fall in auricular pressure results in a slight rise in systolic pressure and a diminution in diastolic pressure in the ventricle. One can see this in Fig. 9.

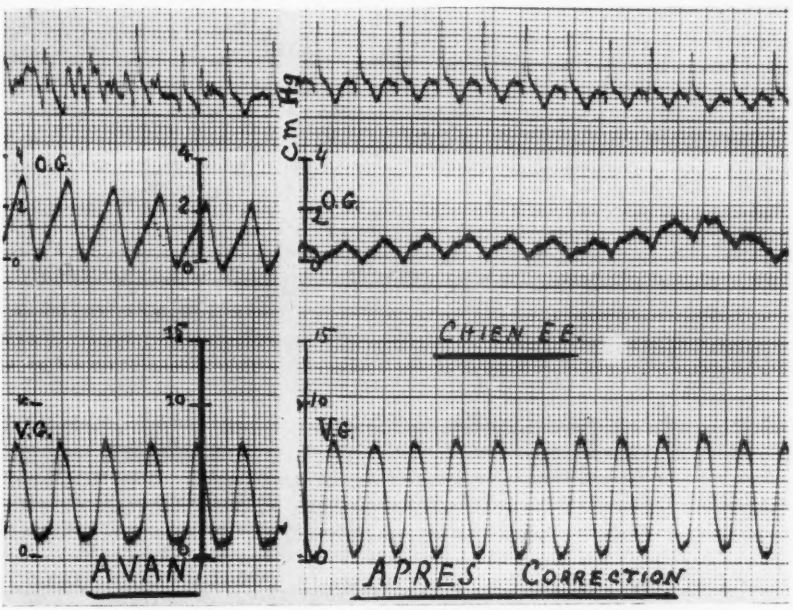


Fig. 9.—*A*, The left auricular and ventricular pressure curves of a dog with an experimental mitral insufficiency. *O.G.*, Left auricle. *V.G.*, Left auricle. The pressures are measured in centimeters of mercury.

B, The same pressures of the same dog after correction of the mitral regurgitation by our prosthesis.

DISCUSSION AND CONCLUSION

The conditions which have led us to use our prosthesis were the following: (1) to use a round and smooth prosthesis, (2) to fix it under the posterolateral valve by a threaded transventricular rod blocked by a lock-nut system, and (3) to gain, by the ventricular contraction toward the septum, a systolic closing of the mitral orifice.

We have endeavored to determine the tolerance of our prosthesis. First, we have attempted to avoid the production of any intracardiac thrombosis. In

practice, any ball badly gauged for the mitral orifice, inadequately fixed, or in a wrong place, results in a thrombosis, always fatal. This, in our opinion, explains the failure of any mobile prosthesis in the ventricle. Following the operative technique described, the ball is put into position in less than an hour. The immediate postoperative progress is uneventful. The later results were studied after an interval of 23 months. Clinically, the prosthesis has been well tolerated. All the animals have lived normally among the others. Microscopically, the tolerance of the ball is proved by the covering of vascular connective tissue which incorporates it in the myocardium. This covering develops as early as the second month. Thus, the prosthesis quickly loses the characteristics of a foreign body, and becomes a natural element of the myocardium. It acts as a shelf support holding up the posterolateral valve and, in addition, by its volume, it partly occludes the area of regurgitation.

Our theoretical ideas on the value of the prosthesis had to be verified by experiment. We have been able to create a mitral insufficiency in a certain number of animals. Immediately afterward, during the same operation, introduction of our prosthesis has caused the disappearance of all the hemodynamic signs of regurgitation. No dog of the last group survived, death being caused by shock and, above all, by hemorrhage due to the creation of the mitral insufficiency and the use of heparin for a continuous pressure reading.

Thus, we believe that we have shown our prosthesis to be well tolerated by the heart and efficient for the correction of mitral insufficiency. Hence, its use on man is indicated. We will give the results in a later report.

REFERENCES

1. Letulle: Traité d'anatomie pathologique, Paris, 1937.
2. Haygraft, J. B.: The Movement of the Heart Within the Chest Cavity and the Cardiogram, J. Physiol. **12**: 438, 1891.
3. Lundin, G.: Mechanical Properties of Cardiac Muscle, Acta physiol. scandinav. **7**: 7 (supp. 20), 1944.
4. Rushmer, R., and Crystal, D. K.: The Functional Anatomy of Ventricular Contraction, Cir. Res. **1**: 162, 1953. Changes in Configuration of the Ventricular Chambers During the Cardiac Cycles, Circulation **4**: 211, 1951.
5. Thal, N., and Rushmer, R. F.: The Mechanics of Ventricular Contraction; Cinefluorographic Study, Circulation **4**: 219, 1951. Thal, N.: Factors Influencing Stroke Volume. A Cinefluorographic Study of Angiocardiography, Am. J. Physiol. **168**: 509, 1952.
6. Bailey, C. P., O'Neill, T. T. E., Glover, R. P., Jamison, W. L., and Redondo-Ramirez, H. P.: Surgical Repair of Mitral Insufficiency, Dis. Chest **19**: 125, 1951.
7. Brock, R. C.: The Surgical and Pathological Anatomy of the Mitral Valves, Brit. Heart J. **14**: 489, 1952.
8. Hurwitt, E. S.: Demonstration of the Function of the Mitral Valve. (Film.)
9. Bailey, C. P., Bolton, H. E., and Redondo-Ramirez, H. P.: Surgery of the Mitral Valve, S. Clin. North America **32**: 6, 1952. Congrès Soc. Int. Angiologie, Lisbonne, Sept., 1953.
10. Harken, D. E.: The Surgical Correction of Mitral Insufficiency, Congrès Soc. Int. Angiologie, Lisbonne, 1953.
11. Davila, J. C., Mattson, W., O'Neille, T., and Glover, R. P.: A Method for the Surgical Correction of Mitral Insufficiency, Surg., Gynec. & Obst. **98**: 407, 1954.
12. Chalnot, P., Benichoux, R., and Chardot, C.: Traitement chirurgical de l'insuffisance mitrale, étude expérimentale d'une prothèse intra-cardiaque, Communication au Congrès Soc. Int. Angiologie, Lisbonne, Sept., 1953.
13. Chalnot, P., Benichoux, R., Chardot, C., and Frisch, R.: L'insuffisance mitrale expérimentale et sa correction par une prothèse en matière plastique, Arch. mal. coeur, 315, 1954.
14. Chalnot, P., Benichoux, R., and Chardot, C.: Le problème chirurgical de l'insuffisance mitrale, Lyon chir. **49**: 552, 1954.

INTRADIAPHRAGMATIC CYSTS

HOWARD J. KESSELER, M.D., AND HERBERT C. MAIER, M.D.
NEW YORK, N. Y.

INTRADIAPHRAGMATIC cysts are rare and their preoperative diagnosis is uncertain. In recent surgical literature, we found only seven cases of cysts within the diaphragm.[1-6] To these we add an intradiaphragmatic bronchogenic cyst. These eight cases include only those cysts which seemed to be actually within the musculature of the diaphragm. Cysts attached or lying adjacent to the diaphragm are much more common and are not discussed here, although embryologically related to the intradiaphragmatic cysts.[7-10]

CASE REPORT

A 41-year-old white woman was hospitalized because roentgenograms of the chest had revealed a mass in the region of the left leaf of the diaphragm. She was essentially asymptomatic although she had a slight dry cough. Chest roentgenograms had been taken two years and one year previously. Originally these films had been read as negative but on re-examination showed the same oval area of increased density overshadowed by the cardiac silhouette (Fig. 1). Only a slight increase in size had occurred in a two-year period. Roentgenoscopy indicated that the lesion moved with the diaphragm and distorted slightly the adjacent diaphragmatic contour in some phases of respiration. Roentgenogram of the chest in the right lateral recumbent position suggested that there was a slight alteration in the shape of the lesion with change in position. This film had been taken to determine whether the mass extended below the diaphragm, but overlying densities obscured the lower portion of the lesion. A diagnosis of possible cystic lesion in or near the diaphragm was made.

An exploratory operation was performed in the lateral position through the left eighth interspace. The pleural cavity was free of adhesions and fluid. The lung was normal. In the posterolateral portion of the diaphragm a localized elevation of the diaphragm, which at first glance suggested partial eventration, was noted. Incision in the overlying diaphragmatic pleura exposed a large multiloculated cyst within the musculature of the diaphragm and intimately associated with it. The inferior aspect of the cyst extended toward the peritoneum. The major portion of the cyst was directed toward the pleural cavity. The blood supply consisted of a 4 mm. artery apparently arising directly from the aorta. This artery was accompanied by a vein at the medial aspect of the cyst. These vessels were ligated and the cyst easily excised without penetrating the peritoneum. The postoperative course was uneventful.

Pathologic examination revealed a 9 by 7 by 3.5 cm. multiloculated, thick-walled cyst containing a tan opalescent watery material. Microscopic examination showed that the cyst was lined by ciliated columnar epithelium supported by a loose connective stroma and smooth muscle. Intimately associated with the smooth muscle of the cyst wall was the striated muscle of the diaphragm. The diagnosis was bronchogenic cyst.

PATHOLOGY

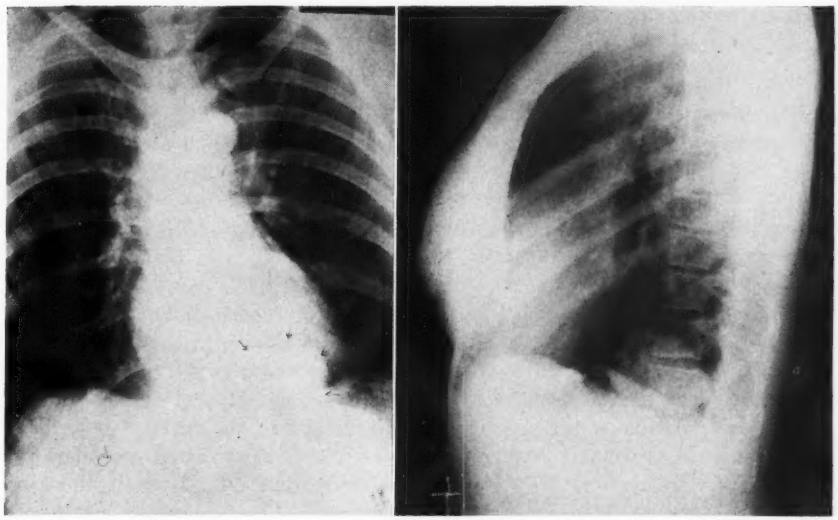
The eight intradiaphragmatic cysts reported fell into three groups (Table I). There were three cases of mesothelial cyst, two bronchogenic

Received for publication Jan. 18, 1955.
From the Surgical Service, Lenox Hill Hospital, New York, N. Y.

TABLE I

AUTHOR	HISTORY	LOCATION	SPECIAL DIAGNOSTIC STUDIES	OPERATION	FINDINGS	PATHOLOGY
Robson and Collis[1]	22-year-old man. Low chest pain	Right diaphragm in posterior costophrenic angle	Casoni test negative; pneumothorax failed because of obliterative pleuritis	Thoracotomy and excision	Thick-walled cyst containing granulations, partially calcified	Cyst of doubtful etiology, probably tuberculous
Scott and Morton[2]	29-year-old man. Chest pain; nonproductive cough; dyspnea	Left diaphragm in dome	Casoni test negative	Exploratory laparotomy; splenectomy; excision of cyst	Thick-walled trabeculated cyst containing chocolate-colored fluid, partially calcified	Primary cyst of diaphragm; origin undetermined, lined with single layer cuboidal epithelium
Nylander and Viikari[3]	17-year-old male. Persistent abdominal pain following appendectomy	Right cardiophrenic angle	Pneumothorax	Thoracotomy and excision	Thick-walled cyst containing clear fluid	Mesothelial cyst
Clagett and Johnson[4]	39-year-old woman. Asymptomatic; lesion found on survey	Left diaphragm anterior axillary line		Thoracotomy and excision	Thick-walled fibrous cyst containing puttylike material	Fibrous-walled cyst
Cruickshank and Cruickshank[5]	41-year-old man. Asymptomatic; lesion found on survey	Right diaphragm near cardiophrenic angle	Pneumoperitoneum	Thoracotomy and excision	Thin-walled bluish cyst	Mesothelial cyst, low cuboidal epithelium
Cruickshank and Cruickshank[5]	49-year-old woman. Slight exertional dyspnea	Left diaphragm near cardiophrenic angle		Thoracotomy and excision	Thin-walled bluish cyst	Mesothelial cyst, low cuboidal epithelium
Bolivar[6]	45-year-old man. Right lumbar pain	Right diaphragm	Retrograde pyelogram; retroperitoneal oxygen insufflation	Thoracotomy and excision	Multiloculated cyst containing clear white substance	Bronchogenic cyst lined by ciliated columnar epithelium
Kesseler and Maier	41-year-old woman. Dry cough	Left diaphragm	Left lateral recumbent radiographs of chest	Thoracotomy and excision	Multiloculated cyst containing tan opalescent substance	Bronchogenic cyst lined by ciliated columnar epithelium

cysts, and the third group consisted of three cases of a thick-walled fibrous cystic lesion of uncertain origin as described by Scott and Morton,[2] Clagett and Johnson,[4] and Robson and Collis.[1] The first two groups represent forms of embryonic sequestration of mesothelial or pulmonary elements which have lost continuity with their parent tissue.



A. *B.*

Fig. 1.—*A*, Posteroanterior roentgenogram with arrows indicating an oval shadow of increased density partly obscured by the cardiac silhouette. Note the relationship to the diaphragm.

B, Left lateral projection shows the mass to be posterior. The outline of both leaves of the diaphragm appears separate from the mass. This film did not suggest that the cyst was intradiaphragmatic.

The mesothelial cysts were described by Nylander and Viikari[3] and Cruickshank and Cruickshank.[5] The latter authors ascribe the development of such cysts as resulting from the pinching off of the advancing edges of the septum transversum, the pleuropericardial, and the pleuroperitoneal membranes as they grow toward each other and fuse to form the diaphragm. Errors in the development of these three structures account for the increased incidence of cysts in and just above the diaphragm.[5, 7-10]

The second form of sequestration noted in this group of cases is the bronchogenic cyst. The widespread sites of bronchogenic cysts in the thorax have been discussed by Maier[11] in relation to their symptomatology and diagnosis. The vascular factors in the development of bronchogenic sequestrations have been described and their significance discussed by Pryce, Sellors, and Blair,[12] and Bruwer, Clagett and McDonald.[13] It seems probable that the cysts seen in the mediastinum, diaphragm, and upper abdomen represent an early embryological abnormality which develops because of the maintenance of the dorsal vascular anlage. According to Pryce[14] cells of the pulmonary

ridge are held dorsally by these vessels as the main pulmonary cell mass grows ventrally and caudally. These cell nests thereby lose continuity with their parent tissue, retain their systemic blood supply, and develop independently in the mediastinum, diaphragm, or abdomen.[15-17]

The origin of fibrous cysts without a characteristic lining is uncertain. It is difficult to ascertain whether such lesions are of congenital or acquired origin. Similar masses are occasionally encountered in the mediastinum.

DIAGNOSIS

The diagnosis of intradiaphragmatic cyst is usually made at operation rather than preoperatively since the cyst cannot easily be differentiated from a tumor mass. Primary neoplasms of the diaphragm are more common than cysts and their prognosis is more serious. In a recent review by Crimm and Kiechle,[18] 38 cases of primary tumor in the diaphragm were analyzed. Sixteen were benign and twenty-two were malignant tumors. In this collected series, about 58 per cent of the tumors primary in the diaphragm were sarcomas.

Other conditions which may enter into the differential diagnosis of a cyst in the diaphragm are basilar lung lesions, partial eventration of the diaphragm, cysts of the pericardium or pericardiophrenic angle, diaphragmatic hernias, tumors of the liver, echinococcus cysts, intramural tumors of the esophagus or cardia of the stomach, and neoplasms of the adrenal or kidney.

Symptoms associated with cysts in the diaphragm varied considerably and none are pathognomonic. Four of the cases were asymptomatic and represented chance findings on mass chest surveys. The other four cases had low chest or abdominal pain, shortness of breath, or a nonproductive cough.

Posteroanterior and lateral roentgenograms of the chest will usually demonstrate the lesion. Occasionally the cyst may be overlooked due to superimposition of the cardiac silhouette or because the density does not project sufficiently above the shadow of the diaphragm. The lateral recumbent roentgenogram may indicate a change in shape of the lesion suggestive of its cystic nature, or demonstrate an infradiaphragmatic projection. Roentgenoscopy and barium studies of the esophagus, stomach, and colon will assist in ruling out lesions of the esophagus, hiatus hernia, and herniation through the foramen of Morgagni. Sectional body roentgenograms will help distinguish lesions in the lung. Retrograde pyelography and retroperitoneal oxygen insufflation may be used when a question of suprarenal or renal origin of the lesion arises. Beck, Clough, and Brochu[19] recommended pneumoperitoneum to distinguish partial eventration of the diaphragm from tumor in the liver, herniations or a lesion in the diaphragm. If a partial eventration of the diaphragm can be demonstrated, surgical exploration may not be necessary. If there is any calcification in the lesion, tuberculosis, or echinococcus cyst must be considered. The Casoni intradermal skin test may help to rule out an echinococcus cyst.

TREATMENT

Although cysts of the diaphragm are usually not serious lesions, inability to differentiate them definitely from primary neoplasms of the diaphragm,

which are not infrequently malignant, makes surgical intervention necessary. A low posterolateral thoracotomy approach is recommended. The surgeon must ascertain the nature of the intradiaphragmatic lesion in order to determine the method of excision. Removal of a cyst will not present the problem of diaphragmatic reconstruction posed by some connective tissue tumors of the diaphragm. In excision of a bronchogenic cyst, the surgeon should remember that the pedicle in the region of the aorta may contain an artery of fair size which should be carefully dissected out.

SUMMARY

Cysts within the diaphragm are rare and their diagnosis preoperatively is difficult. Most are discovered roentgenologically in a person with few or no symptoms. Surgical excision by the thoracic approach is usually recommended because the cyst cannot with certainty be differentiated from more serious lesions. A review of some surgically treated cases has been presented and a personal case of intradiaphragmatic bronchogenic cyst is reported. Mesothelial, bronchogenic, and thick-walled cysts of uncertain origin are apparently the most common types of cyst to be found within the diaphragm. Similar cysts are found more often merely attached to the diaphragm or located in adjacent areas.

REFERENCES

1. Robson, K., and Collis, J. L.: Tumors of the Diaphragm With Report of a Diaphragmatic Cyst, Brit. J. Tubere. **38:** 3, 1944.
2. Scott, O. B., and Morton, D. R.: Primary Cystic Tumor of the Diaphragm, Arch. Path. **41:** 645, 1946.
3. Nylander, P. E. A., and Viikari, S. J.: A Study of Intrathoracic Cysts Arising From the Diaphragm, Ann. chir. et gynaec. Fenniae **37:** 99, 1948.
4. Clagett, O. T., and Johnson, M. A., III: Tumors of the Diaphragm, Am. J. Surg. **78:** 526, 1949.
5. Cruickshank, G., and Cruickshank, D. B.: Intradiaphragmatic Mesothelial Cysts, Thorax **6:** 145, 1951.
6. Bolivar, J.: Quiste Ciliado Intradiaphragmatico, Bol. Liga contra cáncer **27:** 110, 1952.
7. Pickhardt, O. C.: Pleurodiaphragmatic Cyst, Ann. Surg. **99:** 814, 1934.
8. Weber, F. P., and Schwarz, E.: Cyst of the Thorax Outside the Parietal Pleura, Brit. M. J. **1:** 851, 1934.
9. Aufses, A., and Oseosohn, R.: Mesothelial Cyst of the Diaphragm, J. Mt. Sinai Hosp. **16:** 125, 1949-50.
10. Drash, E. C., and Hyer, H. J.: Mesothelial Mediastinal Cysts, J. THORACIC SURG. **19:** 755, 1950.
11. Maier, H. C.: Bronchogenic Cysts of the Mediastinum, Ann. Surg. **127:** 476, 1948.
12. Pryce, D. M., Sellors, T. H., and Blair, L. G.: Intralobar Sequestrations of the Lung Associated With an Abnormal Pulmonary Artery, Brit. J. Surg. **35:** 18, 1947.
13. Bruwer, A., Clagett, O. T., and McDonald, J. R.: Anomalous Arteries to the Lung Associated With Congenital Pulmonary Abnormalities, J. THORACIC SURG. **19:** 957, 1950.
14. Pryce, D. M.: Lower Accessory Pulmonary Artery With Intralobar Sequestration of Lung. A Report of Seven Cases, J. Path. & Bact. **58:** 457, 1946.
15. Valle, A. R., and White, M. L., Jr.: Subdiaphragmatic Aberrant Pulmonary Tissue, Dis. Chest **13:** 63, 1947.
16. Fischer, H.: Quoted by Muller, H.: Die Nebenlungen. In Henke, F., and Lubarsch, O.: Handbuch der speziellen pathologischen Anatomie und Histologie, Berlin, 1928, Julius Springer,Vol. 3, Part 1, p. 578.
17. Findlay, C. W., Jr., and Maier, H. C.: Anomalies of the Pulmonary Vessels and Their Surgical Significance, Surgery **29:** 604, 1951.
18. Crimm, P. D., and Kiechle, F. L.: Fibrosarcoma of the Diaphragm, J. THORACIC SURG. **23:** 360, 1952.
19. Beck, W. C., Clough, D., and Brochu, J.: Partial Eventration of the Diaphragm. Differential Diagnosis and the Use of Pneumoperitoneum, Guthrie Clin. Bull. **23:** 212, 1954.

TRAUMATIC RUPTURE OF THE ESOPHAGUS

(With a Report of 13 Cases)

John W. Overstreet, M.D., Houston, Texas, and
Alton Ochsner, M.D., New Orleans, La.

TRAUMATIC rupture of the esophagus is a catastrophic accident which is increasing in frequency and one that is associated with prohibitive mortality and morbidity unless early diagnosis, vigorous resuscitation, and definitive surgical therapy are carried out. The pathologic anatomy of the lesion may vary considerably with the rupturing agent; whether it be by diagnostic or therapeutic endoscopy, an ingested foreign body, a penetrating missile, or by an intrinsic force engendered by the patient himself. The previous pathological state of the esophagus may also greatly influence the type of surgical therapy to be employed; i.e., drainage, a primary repair, or resection and anastomosis.

ETIOLOGY

With the increasing use of diagnostic and therapeutic endoscopy, it is not surprising that these procedures are the leading cause of traumatic rupture of the esophagus. Jemerin[5] reported more than a 100 per cent increase in traumatic esophageal ruptures following endoscopy at Mt. Sinai Hospital in the last decade in comparison with the previous decade. Seybold[10] reported 21 cases in the first thirty-six years of the Mayo Clinic, with an additional 29 cases during the years of 1943 through 1949. The Tulane Thoracic Surgery Service of the Charity Hospital in New Orleans saw in consultation and treated 9 cases of traumatic perforations of the esophagus from July, 1950, until June, 1953, and saw 4 other cases in consultation, one at the Charity Hospital in New Orleans and 3 cases at the H. P. Long Charity Hospital in Pineville, Louisiana. Nine of the cases to be reported here were produced during endoscopic manipulations by other services or outside physicians; 8 occurred in the Charity Hospital and one patient was referred to this hospital fifteen hours after an attempted removal of a chicken bone by bouginage. Four cases were perforations which involved the cervical esophagus and were produced by penetrating missiles. The increasing frequency of rupture seems to parallel the increasing frequency with which esophageal and gastric endoscopy is being performed. The endoscopic procedures that seem to be the most hazardous are dilatations for strictures and achalasia, and the removal of foreign bodies.

Penetrating missile injury of the esophagus is relatively rare in civilian practice and when seen it is usually of the cervical esophagus, as is true in the cases reported here. The thoracic esophagus is so surrounded by vital structures that injury to the viscus is commonly associated with fatal injury to the heart or great vessels.

From the Department of Surgery, Tulane University School of Medicine and the Tulane Surgical Service, the Charity Hospital of Louisiana, New Orleans.
Received for publication Jan. 19, 1955.

Another form of traumatic rupture of the esophagus that is receiving considerable attention in recent literature (Anderson,[1] Barrett,[2] Carter,[4] Mackler,[7] Olsen,[8] and Samson[9]) is the so-called "spontaneous" rupture of the esophagus. Of 104 proved cases,[1] almost without exception the accident has followed prolonged or forceful emesis, usually the result of gluttony and, less commonly, in postoperative and self-induced vomiting.

PATHOGENESIS

The occurrence of rupture from instrumentation is due to technical faults, an uncooperative patient, or severe disease of the esophagus, and is frequently due to a combination of these factors. In 8 of the 9 cases reported here, local anesthesia was used for instrumentation, and in 3 of the cases, the patients were quite elderly, being 78, 79, and 88 years of age, respectively. These factors may have added to the technical difficulties. Rupture may occur at any level, although the most common sites have been in the cervical esophagus immediately adjacent to the cricopharyngeus "sphincter," and at and immediately above the esophageal hiatus, as both sites are anatomical areas of fixation and narrowing of the esophagus. In cervical esophageal ruptures during endoscopy, it is our feeling that the tear is produced in the fragile viscus by the rigid scope as unusual pressure is exerted to overcome the resistance of the cricopharyngeus muscle. The scope becomes displaced during the maneuver causing a low hypopharyngeal rupture, or as the "sphincter" resistance is suddenly overcome the inflexible tube strikes the fixed posterior esophageal wall with considerable force and a perforation results. In all 6 of our cases in which a primary repair of an endoscopic tear of the cervical esophagus was carried out, the rupture was on the posterior wall immediately adjacent to the cricopharyngeus muscle. Five cases were below and 1 was above the cricopharyngeus. It is apparent that in the manipulation of impacted foreign bodies, the hazard of esophageal perforation may be considerably increased. It is our opinion that, after a reasonable attempt has been made, it is better to proceed with formal esophagotomy with removal of any foreign bodies under direct surgical vision rather than to persist in efforts at endoscopic removal.

In dilatation for strictures and for achalasia, considerable force must often be used to achieve an effective therapeutic result and in cases of advanced local pathology, the hazard of rupture may be considerable. In 600 cases of achalasia at the Mayo Clinic, Olsen and associates[8] report 10 cases of rupture during treatment by dilatation.

In considering the pathogenesis of "spontaneous" rupture of the esophagus, it has been shown that anatomically the inferior esophageal segment is the weakest area in the esophagus. This is probably due to the spiral arrangement of the lower circular muscle fibers as they form the functional "inferior esophageal sphincter," as well as to the spreading out of the longitudinal muscle fibers as they extend to and become continuous with the middle and outer layer of the gastric musculature (Kay[6]). It has been shown experimentally that the musculature ruptures first and that that is followed by a

diverticulum-like protrusion of the mucosa which is the last to give way (Mackler[7]). In the course of repeated vomiting, esophageal obstruction may occur due either to an impacted bolus or to a functional obstruction caused by incoordination of relaxation throughout the esophagus brought on by fatigue, or to spasm caused by the action of the acid gastric juice as it is expelled. In the face of such obstruction, either mechanical or functional, sufficiently high intraesophageal pressures must occasionally occur as to result in traumatic rupture of the organ.

"Spontaneous" rupture occurs almost without exception immediately above the esophagogastric junction on the left posterolateral wall and appears as a linear slit, with eversion of the mucosa, in an otherwise normal-appearing esophagus. Experimentally, the introduction of five pounds of air pressure into an esophagus with both orifices closed will cause an exactly similar lesion in 95 per cent of the cases (Mackler[7]). Wangensteen[11] believes that the underlying etiology is peptic esophagitis due to gastric regurgitation, but biopsies taken at operation have failed to substantiate this theory in many cases (Samson,[9] Mackler[7]).

DIAGNOSIS

The diagnosis of traumatic rupture of the esophagus can be made without undue difficulty, regardless of the mechanism of rupture, if the likelihood of the accident is kept in mind. At endoscopy, rupture is frequently not recognized as having occurred at the time and the endoscopist may be reluctant to accept such a possibility until the diagnosis is confirmed. In only 2 of the 9 cases occurring at endoscopy, did the endoscopist recognize immediately that rupture had probably occurred.

Rupture of the thoracic esophagus is commonly associated with a more fulminating onset and progression of symptoms than is the perforation of the cervical esophagus. This fact is due to the immediate contamination of the mediastinal space which gives rise to progressive mediastinal emphysema and compression and is accompanied or followed shortly by involvement of the pleural space with effusion, collapse of the lung, and possibly signs of a tension pneumothorax. A patient who complains of excruciating cervical or thoracic pain during or shortly after endoscopy, forceful vomiting, or a penetrating neck wound, followed by the appearance of respiratory distress, variable shock, dysphagia, and interstitial emphysema should strongly be suspected of having a ruptured esophagus. Supportive therapy and confirmatory diagnostic procedures must be instituted immediately as an emergency. Mackler[7] states, "a history of sudden thoracic pain occurring during or shortly after the act of vomiting followed by the appearance of interstitial emphysema at the base of the neck, constitutes sufficient evidence to warrant a left thoracotomy." If the rupture is at or adjacent to the esophageal hiatus, severe epigastric pain and a rigid abdomen may be found (as was present in Case 3), but the associated respiratory symptoms of dyspnea, grayish cyanosis, a short grunting type of respiration, and evidence of hypoxia should direct attention to the thorax as the probable site of the lesion. Samson[9] has stressed the

development of a nasal twang to the patient's voice which may precede the appearance of the supraclavicular subcutaneous emphysema, the latter being one of the dominant physical findings in most cases.

In ruptures of the cervical esophagus, there is usually exquisite local tenderness, crepitus, and the patient holds the neck quite rigid in order to resist any local movement. Again this lesion is associated with dysphagia, salivation, and dysphonia.

An erect posteroanterior x-ray of the chest taken so as to include the diaphragm and upper abdomen should be obtained in all cases of suspected rupture of the esophagus. If the thoracic esophagus is ruptured the roentgenogram will usually show mediastinal emphysema, with or without demonstrable fluid, and pleural involvement in the form of hydrothorax or pneumothorax. These findings may or may not be present in cervical ruptures as they would depend upon the duration of the rupture and upon whether or not the mediastinal pleura has been penetrated. A lateral cervical x-ray will show air in the cervical tissues, especially behind the esophagus, pushing the visceral compartment anteriorly. A Lipiodol swallow, never barium, under fluoroscopy which shows extravasation into the periesophageal tissues is confirmatory of the diagnosis and was present in each of the 11 of our cases in which the procedure was done. In Case 7 this was not deemed necessary, since the perforation was visualized at the time of original endoscopy. Usually esophagoscopy is neither indicated nor desirable in these cases.

"Spontaneous-traumatic" rupture of the esophagus must be considered in the differential diagnosis of any upper abdominal emergency; of spontaneous pneumothorax, and of acute coronary disease. Before the lesion was widely recognized, some patients were operated upon for ruptured duodenal and gastric ulcer with the true lesion remaining unrecognized, causing embarrassment to the surgeon and yielding no particular benefit to the patient (Carter[4]).

THERAPY

As stressed by Samson,[9] the treatment of a ruptured esophagus should be that which applies to the rupture of any hollow viscus. The mere fact that the viscus lies in the neck or the thorax in no way materially affects the problem. Rapid resuscitation, of which surgery is an integral part (Beecher[3]), definitive surgical repair following débridement and lavage of contaminated fascial spaces, vigorous supportive therapy in the form of complete and rapid pulmonary expansion, constant tracheobronchial toilet, effected by tracheotomy if necessary, whole blood, and massive combined antibiotic therapy constitute the fundamentals of the treatment of a ruptured esophagus. Following these principles, Weisel[12] has recently reported 7 consecutive cases so treated, with survival and without major complications in any of them.

A high mortality and higher morbidity rate accompany drainage procedures alone during the stage of contamination, which may be as long as twenty-four hours postrupture or more depending upon the underlying esophageal pathology and the treatment or lack of treatment which the patient receives prior to surgery. Five of 6 such cases collected by Samson[9] were

fatal and the sixth case showed prolonged morbidity with pleural and mediastinal sepsis. If a patient survives the stage of contamination, and an invasive infection is present with some degree of localization, drainage procedures are of value but even then the mortality is considerable and the morbidity high.

Definitive repair in such late cases may not be attended with a high percentage of primary healing; however, except in the face of frank abscess formation we believe that primary repair should be attempted. These patients appear to be and usually are desperate surgical risks, especially those with rupture of the thoracic esophagus; however, it must be repeated that surgery is the integral part of the resuscitation and the experience has been common that once the mediastinum has been widely opened and decompressed, the condition of the patient has materially improved so that more deliberate débridement and repair can be carried out.

For ruptures of the cervical esophagus, we commonly have used local infiltration anesthesia and made an oblique incision along the anterior border of the sternomastoid muscle, similar to the approach we use for the removal of pharyngoesophageal diverticula. The edema and emphysema in the fascial tissue planes usually make exposure of the esophagus medial to the vascular compartment quite easy. After the perforation is visualized, a two-layered repair is carried out using fine cotton or silk sutures on Atraumatic needles for the mucosal layer with the interrupted sutures so placed that the knots are tied on the lumen side. The outer muscle layer is sutured with similar material placed as horizontal mattress sutures. The closure is transverse so as not to decrease the diameter of the esophageal lumen. The fascial space having been primarily débrided and lavaged with saline, a Penrose drain is placed in the posterior mediastinal pocket and brought out from the lower angle of the wound and the subcutaneous tissues and skin are loosely approximated with cotton sutures. The drain is placed well away from the line of esophageal repair. A culture is taken from the contaminated tissues and the patient is placed on massive combined antibiotic therapy until the results of the cultures and sensitivity tests indicate the specific antibiotic to be used. During the first 48 to 72 hours, the patient is placed in bed in a head-down position in order to facilitate drainage from the upper mediastinum. The patient is started on small amounts of clear oral liquids after twenty-four hours and the diet is then increased slowly.

In perforations of the thoracic esophagus, we feel that in most instances thoracotomy, with wide incision and débridement of the mediastinal pleura, primary repair of the site of rupture, and rapid expansion of the lung by underwater-seal drainage, is the preferable treatment. An occasional case may demand a different approach. Overholt[13] reports a case that he saw eight days after perforation at which time the patient had a bilateral empyema which responded satisfactorily to bilateral tube drainage. In Case 3 the perforation had occurred through the site of a stricture of the supradiaphragmatic esophagus and it was necessary that a resection of the area be done with primary esophagogastrostomy. It was interesting in this case,

that, due to an unavoidable delay of nearly six hours in getting this patient to the operating table, we saw him develop the typical, clinical picture that is seen in a case of ruptured peptic ulcer.

CASE REPORTS

CASE 1.—M. T., a 79-year-old obese white woman, was admitted to Charity Hospital on Dec. 30, 1950. She had choked on a bolus of food at dinner on the same day and was having difficulty swallowing. A general physical examination showed no significant abnormalities and the patient was esophagoscoped under local anesthesia. A large bolus of meat was removed from the pyriform sinus and the endoscopist reported seeing a tumor mass in the esophagus at the 22 cm. level. A biopsy of the lesion was taken.

Within a very short period following endoscopy, the patient became quite restless and dyspneic. She received 6 grains of phenobarbital throughout the night but the restlessness and dyspnea increased. The Thoracic Surgery Resident saw the patient in consultation approximately twenty-six hours after endoscopy. At the time of his examination the patient was irrational, exhibited acute respiratory distress, and was cyanotic. The blood pressure was 102/64 mm. of mercury and the pulse rate was 120 per minute and of poor quality. There was palpable subcutaneous emphysema in the supraclavicular areas and over the anterior thorax. Breath sounds were inaudible over the right hemithorax. An erect roentgenogram of the chest revealed a right tension hydropneumothorax. An endothoracic catheter was placed in the right pleural space and connected to an underwater trap bottle allowing the escape of a large amount of air and several hundred cubic centimeters of a seropurulent fluid. The patient was given nasal oxygen, a whole blood transfusion, a massive dose of parenteral antibiotics, and was operated upon.

Approximately twenty-nine hours after endoscopy, with the patient under gas-oxygen-ether anesthesia, a right posterior mediastinotomy was performed. The blood pressure was not obtainable at the time the incision was made. The posterior portion of the right third rib was resected very rapidly and the parietal pleura was mobilized giving access to the upper part of the posterior mediastinum. A considerable quantity of purulent fluid and air was evacuated. Two soft rubber catheters were introduced into the mediastinal pocket and connected to an underwater trap and the wound was sealed with petrolatum gauze. The entire operative procedure required ten minutes and, as soon as the mediastinum was decompressed, the blood pressure rose rapidly to 90/60 mm. of mercury.

Although the patient showed some improvement in her general condition during the first forty-eight hours after operation, she continued to run an extremely severe febrile course with progressive symptoms of overwhelming toxicity. She developed signs of phlebothrombosis of the left lower extremity and under local anesthesia, a bilateral superficial femoral vein ligation was performed. In spite of massive antibiotic therapy and whole blood transfusions, the patient died on the eighth postoperative day. Unfortunately, an autopsy could not be obtained upon this patient.

Comment.—Due to the length of time from the perforation until we first saw the patient, her advanced age, and apparently moribund condition at the beginning of the operation only a rapid mediastinotomy was done. Although she improved temporarily, the mediastinitis was not controlled. In view of our later experiences and the reported experiences of others, we probably should have continued with a formal thoracotomy with definitive repair of the esophagus after the decompression of the mediastinum had been accomplished and the patient was definitely improved. This case illustrates the high morbidity and mortality rates following other than definitive control of the lesion.

CASE 2.—H. F., a 63-year-old emaciated Negro man, was admitted to Charity Hospital on May 23, 1951. He stated that for the past two months he had noted progressive difficulty with swallowing, first for solid foods and than rapidly thereafter for semisolids and finally for liquids. He was severely dehydrated upon admission. Except for the severe malnutrition, the physical examination revealed no significant abnormalities. A roentgenogram of the chest was interpreted as within normal limits. An esophagogram showed an irregular, constant

filling defect of the esophagus at the level of the aortic arch and extending inferiorly for approximately six cm. Esophagoscopy was performed under local anesthesia on May 29, 1951, and the endoscopist reported "a smooth angular constricting lesion at the junction of the middle and upper one-third of the esophagus with complete fixation of the esophagus." The patient complained of pain in the neck and increasing salivation and dysphagia following the procedure.

We were consulted thirty hours after esophagoscopy and found the patient acutely ill, moderately febrile, disoriented, and with a fast, thready pulse. There was palpable subcutaneous emphysema of the anterior supraclavicular areas. An erect anterior and lateral roentgenogram of the chest showed emphysema of the soft tissues of the neck, a widening of the visceral compartment, and widening of the supracardiac shadow but no pneumothorax. A Lipiodol swallow under fluoroscopy revealed extravasation of Lipiodol into the retroesophageal space at the level of the fourth thoracic vertebra.

The patient was given a whole blood transfusion, nasal oxygen, massive antibiotics parenterally, and was operated upon thirty-four hours after the endoscopic perforation. A left cervical mediastinotomy, under local anesthesia, was done with the evacuation of about 200 c.c. of foul, seropurulent material. A Penrose drain was placed into the posterior mediastinal pocket and the subcutaneous tissue and skin closed loosely with multiple, interrupted, nonabsorbable sutures.

During the initial seventy-two postoperative hours the condition of the patient remained critical, after which he showed progressive improvement. On June 7, 1951, a tube gastrostomy for feeding was done. The patient refused further surgical therapy and on June 19, 1951, was started on a course of deep x-ray therapy. Following the completion of the x-ray therapy, he was able to swallow semisolid foods and was last seen in June of 1952 at which time he was in a preterminal condition with widespread pulmonary metastasis.

Comment.—Due to the frank abscess cavity that was present in the upper part of the posterior mediastinum, no attempt at primary closure of the esophageal defect was made in this case. The exact location of the perforation was not visualized.

CASE 3.—D. B., a 16-year-old undernourished white male, was admitted to Charity Hospital on Jan. 3, 1952. In 1948, in another city, following esophagoscopy for the removal of a foreign body, the patient had developed a right basal empyema that had required right thoracotomy and tube drainage for one month. Since that time, the patient had noted difficulty in swallowing solid foods. Recently the dysphagia had become more marked, and on admission the patient could swallow only very soft foods and liquids.

A roentgengoram of the chest showed an old operative defect in the right ninth and tenth ribs posteriorly. The physical examination gave evidence of chronic malnutrition and a well-healed operative scar in the right posterior chest wall. An esophagogram showed a smooth, linear stricture at the lower end of the esophagus (Fig. 1). Esophagoscopy revealed "a smooth, linear stricture beginning at 36 cm. from the incisor teeth and extending to the cardia."

On Jan. 9, 1952, the esophagus was dilated with a No. 40 F. Hirsch bougie. On Jan. 16, 1952, repeat bouginage with a No. 46 F. bougie was unsuccessful. Immediately following this attempt, the patient complained of severe presternal pain. This was at 10:00 A.M. and the Thoracic Surgery Service was consulted immediately.

On examination we found the patient to be in acute distress, ashen gray in color, and sweating profusely. The pulse was fast and weak, the respirations were rapid and shallow. The patient objected strenuously to being moved. He lay on his right side with the knees drawn up on the abdomen. There was no subcutaneous emphysema palpable and examination of the thorax did not reveal any significant abnormalities at that time. During the course of one hour following the attempted dilatation, the abdomen became very tender and showed a boardlike rigidity. The patient presented the clinical picture of a ruptured duodenal ulcer. An erect roentgenogram of the chest, including the upper abdomen, showed essentially negative intrathoracic findings but a small amount of free air was visible under both leaves of the diaphragm. A Lipiodol swallow revealed extrav-

asation of the oil outside the esophagus 3 to 4 cm. above the diaphragm on the posterior wall with the Lipiodol extending below the diaphragm into the lesser peritoneal sac (Fig. 2).

A diagnosis of traumatic perforation of the distal esophagus at the site of stricture was made. The patient was given a massive dose of antibiotics parenterally (penicillin, streptomycin, and Terramycin), nasal oxygen, a whole blood transfusion, and Demerol for sedation. He was operated upon by one of us (J. W. O.) six hours postperforation and a posterolateral thoracotomy was performed through the left seventh interspace.

Fig. 1.

Fig. 2.

Fig. 1.—Case 3. Esophagogram made prior to dilatation showing high degree of stricture in the lower esophageal segment.

Fig. 2.—Case 3. Lipiodol esophagogram made immediately after perforation which occurred during bouginage. Lipiodol is seen in periesophageal tissues.

Upon opening the chest, the left lung was found to be free and there were approximately 100 c.c. of a cloudy serous fluid in the pleural space. The mediastinal pleura was intact but quite edematous. The lower mediastinal pleura was incised and the esophagus freed with some difficulty, due to extensive scarring present which apparently was secondary to the previous periesophageal infection which had followed the removal of the foreign body. A one-inch laceration was found on the posterior wall of the esophagus immediately above the diaphragm in an area of intense scarring and stricture formation. It was apparent that the perforation could not be closed without compromising the already greatly narrowed esophagus, so a resection of the lower 10 cm. of the esophagus was done

and an esophagogastrostomy performed. The left chest was drained with two large endothoracic catheters connected to a water-seal bottle and the chest incision closed in anatomical layers with interrupted nonabsorbable sutures.

The postoperative course of the patient was uneventful. A Levin tube, which had been inserted into the stomach following the anastomosis, was removed in forty-eight hours and the patient placed on oral liquids. On the sixth postoperative day he was taking a soft surgical diet. He was discharged from the hospital on the eleventh postsurgical day. The patient gained eight pounds during the first postoperative month. He has remained well, eating a full diet without difficulty. An x-ray with a barium meal taken one month after the operation showed a normally functioning stoma without evidence of stricture or esophagitis (Fig. 3).

Fig. 3.—Case 3. Esophagogram one month after esophagogastrostomy showing normally functioning stoma.

Comment.—This patient presents the interesting findings of having survived two apparent esophageal perforations four years apart, the second rupture necessitating immediate esophageal resection with restoration of continuity by esophagogastrostomy. This patient was subsequently seen one year following surgery at which time he was continuing to do well without evidence or symptoms of esophagitis.

CASE 4.—A. S., a 71-year-old Negro man, at 7 A.M. on Sept. 14, 1952, swallowed a chicken bone that lodged in his throat "just below my Adam's apple." He ate a large amount of bread and rice in trying to dislodge the bone, but was unsuccessful. At 11:30 A.M. his local physician passed a bougie in an attempt to dislodge the bone. After the third attempt, the patient developed a severe pain in the midline of the upper thorax posteriorly and noted within a period of five minutes that the neck was becoming swollen. The patient was referred to the Charity Hospital in Lafayette, Louisiana. No thoracic surgeon was available at that institution so the patient was given one million units of penicillin, 500 mg. of Aureomycin intravenously, and referred on to the Charity Hospital

in New Orleans. The patient was first seen in the Emergency Room of the Charity hospital in New Orleans by the Thoracic Surgery Resident at 4:00 A.M. on Sept. 14, 1952. He was semicomatose and exhibited marked dyspnea, dysphagia, limited ability to talk, and marked subcutaneous emphysema of the supraclavicular areas. An erect roentgenogram of the chest revealed extensive mediastinal emphysema with a questionable fluid level visible. A Lipiodol swallow under fluoroscopy showed extravasation into the upper mediastinum. The patient was given a whole blood transfusion, nasal oxygen, massive combined antibiotics parenterally, and was operated upon at 6:00 A.M. on Sept. 15, 1952, approximately eighteen hours after perforation.

The patient was operated upon by one of us (J. W. O.) through a right posterolateral incision, resecting the fifth rib. A complete synechia of the pleural space was found. After freeing the lung, the mediastinal pleura was seen to be fiery red, very edematous, and tense. The azygos vein was ligated and the mediastinal pleura widely opened from the thoracic inlet to below the right inferior pulmonary vein. A considerable amount of foul fluid and air was evacuated along with beans, rice, bread, and undigested lumps of chicken. Three cm. below the inferior pulmonary vein, a chicken bone measuring approximately 4 cm. long by 3 mm. in diameter was removed from the retroesophageal area. No point of perforation could be visualized but in the lower cervical esophagus a perforation on the posterior wall could be palpated. The mediastinal pleura was widely débrided and the entire area lavaged with a large amount of saline. The chest was closed in anatomical layers using interrupted sutures of cotton. The pleural space was drained by two No. 34 F. rubber catheters connected to an underwater drainage bottle. The general condition of the patient improved very markedly as soon as the mediastinum was decompressed. After the thoracotomy incision was closed, the patient was turned to a supine position and the cervical esophagus explored through an oblique incision in the right side of the neck. The perforation was located on the posterior wall at the level of the second tracheal ring. Closure of the defect was carried out using two layers of interrupted sutures of No. 4-0 silk. The wound was closed without primary drainage from the neck, although the cervical retroesophageal area communicated freely with the thoracic mediastinal space that was drained by the two intrapleural tubes.

Postoperatively, the patient did extremely well. He was afebrile in 48 hours and was started on oral fluids at that time. At no time was there evidence of further esophageal leakage. On the fifth postoperative day he developed a small sterile serous effusion on the left side that was aspirated and did not recur. He was given a soft diet on the sixth postoperative day and was discharged on the sixteenth postsurgery day. He was followed in the outpatient clinic at intervals for over one year and had no further difficulties.

Comment.—This case clearly illustrates the major clinical features of traumatic esophageal perforation and the excellent results which commonly follow vigorous resuscitation and definitive surgical therapy.

CASE 5.—L. H., a 54-year-old Negro woman, was admitted to Charity Hospital at 4:00 A.M. on Nov. 12, 1952, complaining of a "bone" stuck in her throat. The admission physical examination was reported as showing no significant abnormalities. Esophagoscopy was performed at 9:00 A.M. on the same day under local anesthesia and the report stated "no foreign body seen." The patient stated that immediately after endoscopy she noted the onset of severe pain in the neck, became progressively short of breath, and developed a swollen neck. She had marked difficulty in swallowing her saliva. In spite of these symptoms, she was discharged from the hospital by the admitting service at 6:00 P.M. the same day.

The patient stated that she became progressively more ill at home and at 4:00 A.M. she returned to the Emergency Room at Charity Hospital. She was first seen by the Thoracic Surgery Resident six hours later. The patient at that time was very dyspneic, moderately febrile, with pain and tenderness in the cervical areas, and extensive subcutaneous emphysema of the face and neck. An erect roentgenogram of the chest showed

no pneumothorax. A Lipiodol swallow under fluoroscopy showed extravasation of the contrast medium outside the esophagus in the upper cervical region. The patient was given a whole blood transfusion, massive combined antibiotics parenterally, nasal oxygen, and transferred to the surgical service.

The patient was operated upon at 2:00 A.M. on Nov. 14, 1952, thirty-nine hours after endoscopy. As anesthesia was induced, the patient developed laryngeal obstruction and an emergency tracheotomy was done. Through a left anterior cervical incision, the esophagus was mobilized and a perforation on the posterior wall immediately below the cricopharyngeus muscle was repaired with two layers of interrupted nonabsorbable sutures. The patient was given liquids by mouth in forty-eight hours and on the fourth postoperative day the signs of a small esophageal fistula were noted. A feeding gastrostomy was done. Her further course was uncomplicated. By Dec. 16, 1952, no evidence of the fistula remained and the gastrostomy tube was removed. She has remained well since that time.

Comment.—In spite of the prolonged duration between perforation and repair, the patient rapidly improved after surgery. The esophageal fistula that developed was apparently quite small and probably could have been controlled by the passage of a soft, plastic feeding tube without resort to gastrostomy.

Fig. 4.—Case 6. Lateral cervical roentgenogram after Lipiodol swallow showing retroesophageal extravasation of contrast media and anterior displacement of the visceral compartment.

CASE 6.—L. M., a 27-year-old Negro woman, was admitted to the H. P. Long Charity Hospital in Pineville, Louisiana, on Feb. 4, 1953, shortly after having been shot three times with a small-caliber pistol. There was a wound of entry above the point of the left shoulder, another to the right of the midline of the middle of the neck anteriorly, and three perforations on the lateral aspect of the right forearm. An erect roentgenogram of the chest revealed a fracture of the left first rib posteriorly but there was no pneumothorax. An esophagogram using Lipiodol revealed extra-esophageal oil in the region of the seventh cervical vertebra with widening of the prevertebral visceral space (Fig. 4).

The general condition of the patient was satisfactory. She was operated upon while receiving a whole blood transfusion and massive combined antibiotics parenterally. This was approximately six hours after the time of injury. The left side of the neck was explored through an incision along the anterior border of the sternomastoid muscle. The point of perforation of the esophagus was found immediately below the cricopharyngeus. The wound was débrided and the defect in the esophagus was closed with separate layers of mucosal and muscular sutures of quilting cotton. The operative wound was closed without drainage using interrupted cotton sutures.

Her postoperative recovery was entirely uneventful. Being able to take a normal diet, she was discharged from the hospital on the fifteenth postsurgery day.

CASE 7.—L. W., a 49-year-old white woman, was admitted to Charity Hospital on Feb. 28, 1953, with a history of massive gastrointestinal bleeding. Extensive clinical investigation revealed no abnormalities other than a large sliding hiatal hernia. Further questioning revealed symptoms compatible with peptic esophagitis. Under local anesthesia, esophagoscopy was performed on March 11, 1953, at 10:00 A.M. Shortly after the procedure, the patient stated she noted the onset of severe pain in the neck and some swelling, both of which became progressively worse and were associated with excessive salivation and difficulty in swallowing. She was seen by the Thoracic Surgery Service the next morning and a clinical diagnosis of esophageal perforation was made. A Lipiodol swallow under fluoroscopy revealed extravasation of the oil outside the esophagus into the neck.

Twenty-eight hours after endoscopy, the patient was operated upon through a left anterior cervical incision and a perforation on the posterior wall of the esophagus was closed in layers with nonabsorbable sutures. Two drains were left in the superior mediastinal space. The patient received intravenous fluids and large doses of combined antibiotics parenterally. Oral fluids were started on the third postoperative day. A small fistula was apparent on the fifth day after surgery. A temporary feeding gastrostomy was done on March 22, 1953, and oral feedings were discontinued until April 1, 1953, when methylene blue taken by mouth showed that the fistula had closed. The gastrostomy tube was removed and the patient's further course was uneventful. She was discharged from the hospital on April 17, 1953.

She was readmitted to Charity Hospital on June 8, 1953, at which time an esophagogram showed no residual defect. One of us (A. O.) repaired the large sliding hernia, using the Allison technique.

Comment.—The immediate response of the patient after surgery was excellent and due to the small size of the fistula that developed, it was probably not absolutely necessary that the feeding gastrostomy be done.

CASE 8.—E. C., a young Negro man, was admitted to Charity Hospital on April 12, 1953, one hour after having been stabbed in the right anterior neck. The blood pressure on admission was 86/50 mm. of mercury. There was brisk arterial bleeding from a 3 cm. laceration in the right side of the neck just above the right clavicle at the anterior border of the sternomastoid muscle. There was subcutaneous emphysema in the left supraclavicular area. The hematocrit was 34 volumes per cent. A roentgenogram of the chest was not abnormal. The patient was operated upon two hours and forty-five minutes after his injury, while receiving whole blood transfusions, and massive combined antibiotics parenterally.

Through a right oblique anterior cervical incision, a large transverse laceration of the posterior wall of the cervical esophagus was found and repaired with an inner layer of No. 3-0 chromic catgut and an outer muscular layer of quilting cotton. The major point of bleeding was from the right superior thyroid artery which was ligated. A small rubber dam drain was brought out through the lower angle of the incision and the subcutaneous tissues and skin closed with multiple interrupted sutures of quilting cotton.

The postoperative course was completely uneventful and a barium swallow on May 4, 1953, showed no residual defect in the esophagus.

CASE 9.—E. T., a 78-year-old white man, was admitted to Charity Hospital complaining of weakness, upper abdominal pain, and recent hematemesis and tarry stools. The general physical examination was not remarkable and roentgenographic studies of the gastrointestinal tract were normal except for a small hiatal hernia and sigmoid diverticulosis.

In order to rule out esophagitis or varices, on April 29, 1953, at 8:00 A.M., the patient was esophagoscoped under local anesthesia. There was difficulty in introducing the esophagoscope and at 9:00 A.M., we were called to the endoscopy room to see the patient. The esophagoscope was still in the esophagus and there was an obvious perforation on the posterior wall just below the cricopharyngeus. The patient was given 1,000,000 units of penicillin, 1 Gm. of streptomycin, luminal, and atropine and was transferred to surgery.

Two hours after the perforation, under local anesthesia, the esophagus was explored through an oblique incision along the anterior border of the left sternomastoid. The perforation was visualized on the posterior wall and a two-layer closure with fine interrupted silk sutures was performed. The integrity of the anastomosis was tested by having the patient swallow methylene blue solution which revealed a water-tight closure. A small rubber drain was left in the upper mediastinum and the operative wound closed. The patient was given oral liquids on the first postsurgery day. With the exception of a severe penicillin rash that developed on the eighth postoperative day his clinical course was completely uneventful.

Comment.—This is the only case in this series in which the endoscopist recognized the site of perforation when it occurred.

CASE 10.—L. J., an 88-year-old undernourished Negro woman, was admitted to Charity Hospital on April 27, 1953, where she was studied extensively for a marked anemia of undetermined etiology. Gastroscopy was performed on May 6, 1953, at 9:00 A.M. and the endoscopist stated that there was "some difficulty in passing the gastroscope." Shortly after the procedure, the patient complained of severe pain in the neck and developed a rising pulse rate, fever, and moderate dyspnea. A roentgenogram of the chest showed subcutaneous emphysema in the base of the neck, bilaterally with a moderate right pneumothorax.

We saw the patient in consultation eight hours after endoscopy. A Lipiodol swallow, under fluoroscopy, showed extravasation of the dye from the upper esophagus. The patient was critically ill at that time. An endothoracic tube was placed in the right pleural space and connected to an underwater drainage bottle. Approximately 300 c.c. of seropurulent fluid and a large amount of air was removed. The patient was given a whole blood transfusion, massive combined antibiotics parenterally, nasal oxygen, and was transferred to surgery.

Under local anesthesia, the cervical esophagus was explored through an oblique incision and a perforation was found on the posterior wall which was repaired with two layers of interrupted sutures of fine silk. A fine rubber dam drain was placed into the superior mediastinum and because of the patient's critical condition and the pulmonary complications, a tracheotomy was performed also. The operation was carried out approximately thirteen hours after the endoscopy.

Postoperatively the condition of the patient steadily improved, the only complication being a persistent middle-lobe atelectasis which required bronchoscopy through the tracheotomy stoma. The patient was given liquids by mouth on the second postoperative day and a soft diet on the seventh day after operation. The endothoracic tube was removed on the third postoperative day as the lung was completely expanded and there was no evidence of pleural infection. A Lipiodol swallow on the thirteenth day showed no esophageal defect.

Comment.—We feel confident this very elderly, critically ill patient would not have survived without vigorous definitive therapy. This case further illustrates the value of tracheotomy in the management of critically ill patients with pulmonary complications.

CASE 11.—L. F., a 64-year-old white woman, was admitted to Charity Hospital with a one-year history of indigestion and epigastric pain that was relieved by alkalis.

On April 19, 1953, the patient vomited about "one pint" of bright red blood and fainted. She was admitted to the Emergency Room in mild shock and shortly thereafter went into deep shock after passing two large, tarry stools and vomiting a small amount of bright red blood. She responded to multiple whole blood transfusions and the bleeding apparently subsided promptly. The patient was studied extensively by proctoscopy, and roentgenographic studies of the entire intestinal tract, as well as hematologic and liver studies, failed to reveal the etiology or source of the bleeding.

On May 18, 1953, abdominal exploration under endotracheal anesthesia was performed. During the course of the operation, a Levin tube was passed with the aid of a laryngoscope by the anesthetist. No demonstrable pathology or cause of the bleeding was found at operation. At the conclusion of the operation, her condition was reported as satisfactory.

At 9:00 A.M. of the first postoperative day, it was noted that the left side of the patient's neck was swollen and tender to palpation and that subcutaneous emphysema was present. A roentgenogram of the neck showed air in the retroesophageal space and a Lipiodol swallow showed extravasation of the contrast medium into the periesophageal tissues in the region of the seventh cervical vertebra.

The patient was operated upon approximately thirty hours after the previous abdominal exploration. The cervical esophagus was explored under local anesthesia. A perforation of the hypopharynx on the left lateral wall was found just above the cricopharyngeus. The tissues were very edematous and indurated. Closure of the perforation was performed by two layers of interrupted nonabsorbable sutures. The patient was acutely ill and disoriented at the time of exploration. A small rubber wick drain was inserted into the upper mediastinum and brought out through the lower end of the wound.

The postoperative course of this patient was quite complicated. Two days after operation, there was clinical evidence of moderately severe electrolyte imbalance which responded to increased amounts of sodium chloride and potassium chloride solutions. On May 22, 1953, a cervical fistula was apparent. In spite of the fistula, she was continued on oral fluids and was showing steady improvement until she was given aureomycin orally on May 29, 1953. She promptly developed a severe diarrhea followed shortly by increasing evidence of partial small bowel obstruction. On June 1, 1953, the abdomen was re-explored and an incomplete small bowel obstruction due to adhesions found. It was also reported that the entire small bowel and colon were extremely hyperemic and edematous. It was felt this picture was compatible with a diffuse enteritis, probably related to the use of the broad-spectrum antibiotic.

Her convalescence was slow thereafter but the cervical fistula progressively decreased in size and closed without further operative procedures.

Comment.—It is felt that in this case the perforation of the hypopharynx occurred either at the time of insertion of the endotracheal tube or during the operative procedure when the Levin tube was passed with the aid of the laryngoscope. The fact that she was recovering from the effects of a general anesthetic and had received narcotics during the afternoon and evening of the day of operation probably prevented the earlier appearance of symptoms referable to the ruptured hypopharynx. Morbidity in this case was extensive but was in large part due to the abdominal complications.

CASE 12.—L. G., a young Negro man, was admitted to the H. P. Long Charity Hospital in Pineville, Louisiana, on May 24, 1953, two hours and fifteen minutes after having been stabbed in the right side of the neck. The wound of entrance was along the anterior border of the sternomastoid muscle and the blade of the knife could be palpated in the depth of the wound. The neck was very tender and there was extensive subcutaneous emphysema but the general condition of the patient was satisfactory. A roentgenogram of the neck revealed a knife blade extending transversely in the lower neck at the level of the fifth cervical vertebra (Figs. 5, *A* and *B*). A roentgenogram of the chest taken in the erect position at the time of admission showed no pneumothorax and a Lipiodol swallow showed extravasation of the oil into the retroesophageal tissues of the neck.

The patient was given a whole blood transfusion, and a massive dose of combined parenteral antibiotics and was operated upon three and one-half hours after injury. The

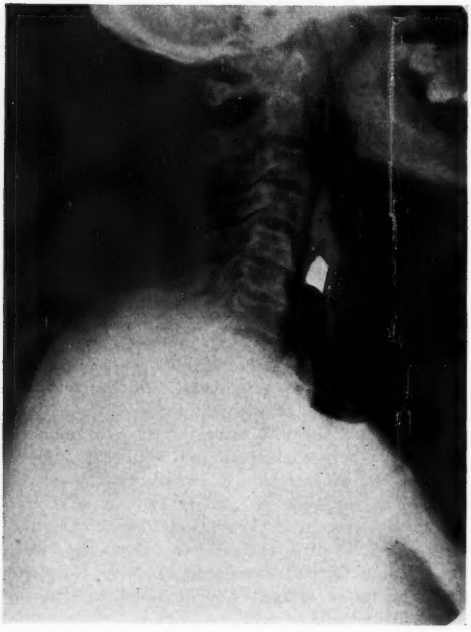


Fig. 5*A*.—Case 12. Lateral roentgenogram of the neck showing presence of foreign body, subcutaneous emphysema, and air in the retrovisceral space.

Fig. 5*B*.—Case 12. Roentgenogram of chest including the cervical area showing a knife blade lying transversely in the neck and extravasation of Lipiodol outside the esophagus.

neck was explored through bilateral oblique incisions and the knife blade was found to lie immediately anterior to the carotid artery, on the right side. The blade had penetrated the esophagus posteriorly giving an entrance and exit wound with a small area of intact esophagus between the openings. The esophageal perforations were closed with interrupted sutures of quilting cotton on the mucosa and the muscle layers. The operative wound was closed without drainage.

The postoperative course was without complications. The patient was given oral liquids on the first postoperative day and the diet was steadily increased. He was continued on large parenteral antibiotic dosage for seven days. The patient was discharged from the hospital on the fourteenth postoperative day as he was eating normally and was asymptomatic.

CASE 13.—D. B., a 23-year-old Negro man, was admitted to H. P. Long Charity Hospital in Pineville, Louisiana, on June 7, 1953, approximately five hours after having been shot in the left midneck immediately lateral to the trachea. The bullet could be palpated in the subcutaneous area of the right shoulder girdle. There was swelling and subcutaneous emphysema in the right supraclavicular fossa. The blood pressure was 130/90 mm. of mercury and the pulse rate was 100 per minute. The general condition of the patient was satisfactory. A lateral roentgenogram of the neck showed subcutaneous emphysema and air in the retroesophageal space. A Lipiodol swallow under fluoroscopy in the anterior and lateral projections revealed extravasation of the oil into the right periesophageal tissues.

Under general anesthesia the neck was explored and a laceration of the esophagus on the posterior wall was found. The operative wound was closed without drainage. The patient was given large doses of parenteral antibiotics. He was given oral liquids on the second postoperative day and was taking a regular diet on the seventh day, at the time of his discharge from the hospital.

Comment.—The response of this patient was without any complications.

SUMMARY

1. Of thirteen cases of traumatic perforation of the esophagus treated by us from July, 1950, to June, 1953, eight were due to diagnostic or therapeutic endoscopy or bouginage, one occurred in the pyriform fossa during attempted passage of a Levin tube with the patient under endotracheal anesthesia, and four were due to penetrating injuries of the neck.

2. All patients were subjected to operation as soon as possible after the diagnosis was made and resuscitative and supportive therapy had been started.

3. Ten of the cases had primary repair with excellent results other than small temporary fistulas which developed in 3 of the cases. The duration of perforation prior to repair in those developing fistulas was forty-four hours, twenty-four hours, and twenty-eight hours, respectively.

4. Mediastinotomy and drainage were done in 2 cases. Case 1 had posterior mediastinotomy and intrathoracic underwater-seal drainage for massive infected pleural effusion and tension pneumothorax twenty-eight hours after perforation. She died on the eighth postoperative day. Case 2 had cervical drainage of a high mediastinal abscess thirty-two hours following perforation during biopsy of a high thoracic esophageal carcinoma.

5. The ages of the patients ranged from 16 to 88 years.

6. The time interval from perforation to surgery varied as extensively as did the ages, the intervals ranging from one and one-half hours to forty-four hours.

7. Of the 8 endoscopic perforations, 5 occurred immediately below the cricopharyngeus sphincter on the posterior esophageal wall, one occurred through a stricture immediately above the esophageal hiatus, and in the 2 in which drainage only was done the site was in the cervical or upper thoracic esophagus, but the opening was not visualized. All four of the penetrating esophageal injuries occurred in the cervical segment.

CONCLUSIONS

In closing, we can say that our experience has paralleled that of others, Samson,[9] Weisel,[12] Mackler,[7] etc., in finding that prompt diagnosis, rapid resuscitation, surgical exploration with débridement of contaminated fascial planes, definitive repair of the esophageal defect, and vigorous postoperative supportive therapy are followed, in a large percentage of cases, by rapid and relatively uncomplicated recovery from this previously highly fatal accident.

REFERENCES

1. Anderson, Robert L.: Rupture of the Esophagus, J. THORACIC SURG. **24**: 369-382, 1952.
2. Barrett, N. R.: Spontaneous Perforation of the Esophagus, Thorax, London **1**: 48-70, 1946.
3. Beecher, H. K.: Early Care of the Seriously Wounded Man, American Lecture Series No. 138, Springfield, Ill., 1952, Charles C Thomas, Publisher.
4. Carter, J. P., Aldrich, E. M., and Drash, E. C.: Spontaneous Rupture of the Esophagus, Surgery **30**: 500-505, 1951.
5. Jemerin, E. E.: Results of Treatment of Perforation of the Esophagus, Ann. Surg. **128**: 971-975, 1948.
6. Kay, E. B.: Observations as to the Etiology and Treatment of Achalasia of the Esophagus, J. THORACIC SURG. **22**: 254-265, 1951.
7. Mackler, S. A.: Spontaneous Rupture of the Esophagus, Surg., Gynec. & Obst. **95**: 345-355, 1952.
8. Olsen, A. M., Harrington, S. W., Moersch, H. J., and Andersen, H. A.: The Treatment of Cardiospasm; Analysis of a Twelve Year Experience, J. THORACIC SURG. **22**: 164-187, 1951.
9. Samson, Paul C.: Postemetic Rupture of the Esophagus, Surg., Gynec. & Obst. **93**: 221-229, 1951.
10. Seybold, W. D., Johnson, M. A., and Leary, W. V.: Perforation of the Esophagus, S. Clin. North America **30**: 1155-1183, 1950.
11. Wangensteen, O. H.: Discussion of Anderson, R. L.: Rupture of the Esophagus, J. THORACIC SURG. **24**: 386, 1952.
12. Weisel, W., and Raine, F.: Surgical Treatment of Traumatic Esophageal Perforation, Surg., Gynec. & Obst. **94**: 337-346, 1952.
13. Overholt, R. H.: Discussion of Anderson, R. L.: Rupture of the Esophagus, J. THORACIC SURG. **24**: 385, 1952.

HEMANGIOMA OF THE MEDIASTINUM

Review of Literature and Report of Case

F. Henry Ellis, Jr., M.D.,* John W. Kirklin, M.D.,* and
Lewis B. Woolner, M.D.**
Rochester, Minn.

VASCULAR tumors are common tumors and are found most frequently in the skin and mucous membranes. They are found also in the central nervous system and abdominal viscera. The hemangioma is one of the commoner vascular tumors, but it is rare for a hemangioma to develop in the mediastinum. In fact, with one exception,[1] most recent reports of large groups of mediastinal tumors fail to mention its occurrence at all. This case was not discussed in sufficient detail to be included in this review. We were, therefore, surprised to encounter five vascular tumors in a recent review at the Mayo Clinic of mediastinal tumors in infants and children.[2] Two of these were hemangiomas, one of which had been reported previously.[3]

A review of the literature (Table I) reveals that all documented cases of this condition have appeared within the last 11 years. Because of the rarity of this condition and the likelihood that it will be encountered more frequently with the increasing use of exploratory thoracotomy for indeterminate mediastinal tumors, the following case is reported. In addition, the literature has been reviewed in an attempt to determine whether any characteristics of this condition may lead to a correct preoperative diagnosis.

REPORT OF CASE

The patient, a 9-year-old boy, was first seen at the Clinic on Nov. 28, 1952.

There was no family history of significant diseases and the patient had been in good health during his early childhood. Because of vague symptoms of easy fatigability, a mobile chest unit thoracic roentgenogram had been taken 3 months before admission. This was reported to be abnormal. There was no history of cough, hemoptysis, dyspnea, thoracic pain, or fever.

Physical examination revealed a blood pressure of 128 mm. of mercury systolic and 80 diastolic, a pulse rate of 76 per minute and a temperature of 98.9° F. There was a soft apical systolic murmur.

The results of laboratory studies, including routine urinalysis, hemoglobin, erythrocyte and leukocyte counts, and erythrocyte sedimentation rate, were within normal limits. The cutaneous reaction to tuberculin was negative.

Roentgenograms of the thorax (Fig. 1) revealed a rounded shadow in the anterior mediastinum projecting into the left side of the thorax. Fluoroscopy of this mass demonstrated pulsations which seemed to be expansile in character.

Because of the presence of an indeterminate mediastinal mass, exploratory thoracotomy was advised. On Dec. 11, 1952, a left posterolateral incision was made and the left side of

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The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

Received for publication Jan. 22, 1955.

*Section of Surgery, Mayo Clinic and Mayo Foundation, Rochester, Minn.

**Section of Surgical Pathology, Mayo Clinic and Mayo Foundation, Rochester, Minn.

TABLE I. PRIMARY HEMANGIOMA OF THE MEDIASTINUM

CASE	AUTHOR	YEAR	SEX AND AGE*	LOCATION IN MEDIASTINUM	SIZE OR WEIGHT	OPERATION	FOLLOW-UP
				Proved Cases, Photomicrographs Available			
1	Adams and Bloch[4]	1944	M34	Right midanterior	18 by 10 by 5 cm.	Incompletely removed	Alive 4 years later
2	Bergstrom[5]	1945	F12 wk.	Right anterior	—	No	Died
3	Bergstrom[5]	1945	F5 wk.	Midanterior	8 by 5.5 cm.	No	Died
4	Seybold et al.[3]	1949	M59	Right midposterior	3.5 by 3.7 by 2.5 cm. 12 Gm.	Completely removed	Alive and well 8 years later
5	Thomas and Chesser[6]	1950	F18	Left midanterior	10 by 7.5 by 6.5 cm. 275 Gm.	Completely removed	Survived operation
6	Schlumberger[7]	1951	M26	Anterior	—	No	Died
7	Schlumberger[7]	1951	M19	Anterior	9 by 5 by 5 cm.	Completely removed	Malignant mediastinal teratoma found subsequently
8	Maggi et al.[8]	1952	M24	Right midanterior	—	No	Died
9	Sebestény[9]	1953	F47	Left midanterior	380 Gm.	Completely removed	Survived operation
10	Grimes et al.[10]	1953	F31	Right superior	6 by 8 cm.	Completely removed	Survived operation
11	Maurer[11]	1953	M38	Left upper anterior	12 by 7 cm.	Completely removed	Alive and well 5 weeks later
12	Valle[12]	1954	M23	Left lower anterior	8 by 10 cm.	Completely removed	Alive and well 18 months later
13	Authors	1955	M9	Left upper anterior	6 by 5 by 4 cm.	Completely removed	Alive and well 2 years later
				Unproved Cases, Photomicrographs Not Available			
14	Horst and Beatty[13]	1951	M20	Left anterior	18 cm. diameter	Completely removed	Alive and well 33 months later
15	Tal'man[14]	1953	F42	Right midposterior	10 by 6 by 6.5 cm.	Completely removed	Alive and well 4½ months later
16	Keegan[15]	1953	F18	Right midanterior	7 by 8 cm.	Exploration, biopsy, x-ray therapy	Alive and well 7 months later
17	Emery and Doxiadis[16]	1953	M8	Left upper anterior	14 by 16 by 8.5 cm.	No	Died
18	Gross[17]	1953	—3mo.	Left superior	—	Exploration, biopsy, x-ray therapy	Alive and well 1 year later
19	Schorr et al.[18]	1954	F56	Left midanterior	5 by 7 cm.	Exploration, biopsy, x-ray therapy	Alive and well 1 year later

*Years unless otherwise specified.

the chest was entered through the bed of the resected fifth rib. High in the anterior mediastinum, a firm tumor mass overlay the aortic arch and extended up to the left innominate vein. The mass was dissected away from the surrounding structures without difficulty. A number of blood vessels which were ligated and divided seemed to enter its superior portion from the mediastinum. The chest was closed in layers after insertion of an intercostal tube through the ninth intercostal space for postoperative drainage.

The patient's postoperative course was uneventful. The chest catheter was removed on the third postoperative day and he was dismissed from the hospital after 8 days. Two years later the child is asymptomatic and the thoracic roentgenograms reveal no significant abnormality.

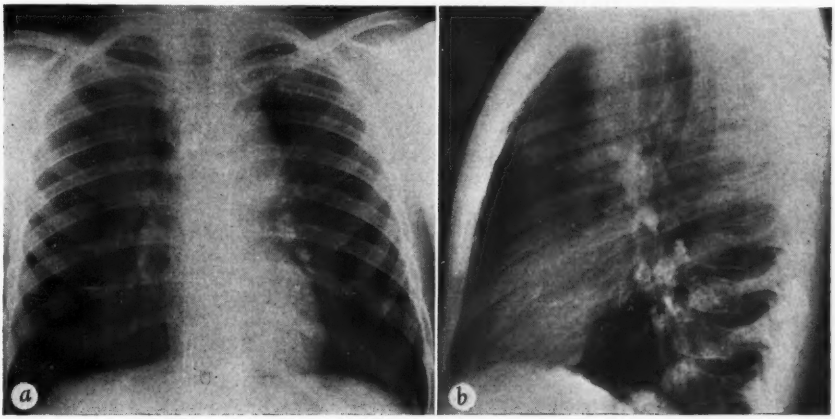


Fig. 1.—Thoracic roentgenograms in a case of mediastinal hemangioma. *a*, Postero-anterior projection; rounded tumor mass overlying the aortic shadow and projecting into the left side of the thorax. *b*, Left lateral view; tumor in the anterior mediastinum.

The specimen measured 6 by 5 by 4 cm. On cut section (Fig. 2, *a*) it was seen to be made up of spongy vascular tissue with cystic spaces. Microscopic examination (Fig. 2, *b*) revealed typical benign cavernous hemangioma. Proliferating smooth-muscle cells were present in the septa.

COMMENT

A hemangioma is a benign neoplasm composed of numerous blood vessels of varying size and admixtures of other mesodermal tissues such as fibrous tissue, smooth muscle, and fat. It may be encapsulated or locally infiltrative, but it does not metastasize.

In reviewing the literature, an attempt was made to include only cases fitting this description in which the hemangioma was limited to the mediastinum. All cases of malignant vascular tumors were excluded. In so doing, some cases previously reported as hemangiomas of the mediastinum have been eliminated while others listed as hemangio-endotheliomas have been included. Hemangiomas of the diaphragm[19] and pericardium[20] were not included in this group of mediastinal hemangiomas. The two cases of Bergstrom[5] (Cases 2 and 3) in which the patients were newborn infants are, however, open to question as possibly being of pericardial or diaphragmatic origin. One case (Case 7) of Schlumberger[7] in which later a malignant teratoma of the mediastinum was found is also open to question.

A total of 19 cases of hemangioma of the mediastinum have been reported, including the case reported here. Thirteen of these are classified as proved cases because photomicrographs compatible with this diagnosis were published in the reports. Six are unproved in the absence of photomicrographs, although in all likelihood they are all authentic cases. It is difficult to explain why no cases were reported prior to 1944.

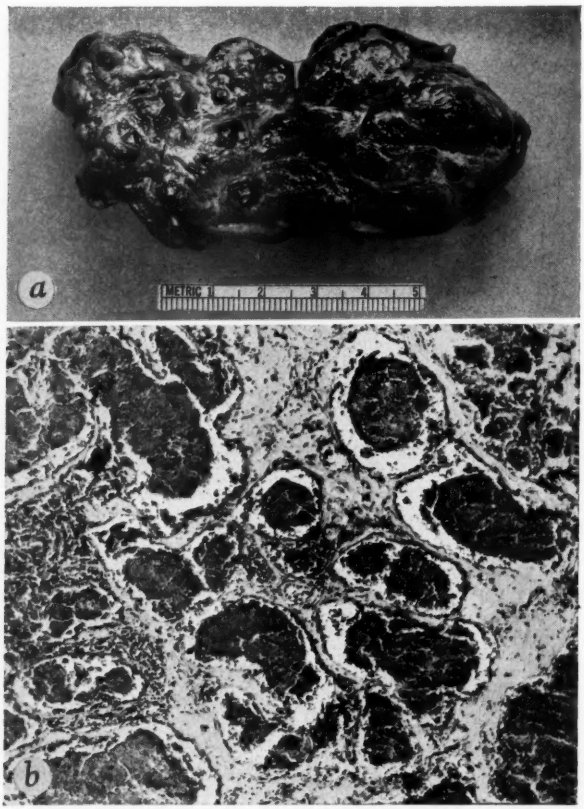


Fig. 2.—*a*, Cut surface of gross specimen of mediastinal hemangioma. *b*, Photomicrograph of *a*; multiple blood-filled spaces with varying amounts of intervening connective tissue and proliferative smooth muscle. (Hematoxylin and eosin; ×75.)

Special Characteristics.—All age groups are represented in this series of 19 cases, beginning with the newborn period up to and including the sixth decade of life. The two sexes were equally affected. No characteristic symptoms were noted, many patients being completely symptom-free until a routine thoracic roentgenogram disclosed the tumor. Symptoms, when present, were the usual ones related to thoracic disease, for example, cough, thoracic pain, fever, and dyspnea.

Roentgenologically, these tumors have a discrete curved outline and may be found either on the right or on the left side. The most characteristic feature of this unusual condition is its location. In only two cases was the tumor located in the posterior mediastinum. In the remaining 17 cases the tumor was anteriorly located, either in the upper, mid-, or lower portion of the anterior mediastinum or in the superior mediastinum. This consistently anterior mediastinal location is shared by only two other types of primary mediastinal tumors, thymomas and teratomas.

Origin and Pathology.—No definite statements regarding the origin of mediastinal hemangiomas are justified from the available data although some speculations can be made. Hemangiomas in general are considered as developing from vascular mesenchyme. This angioblastic tissue remains discrete and separate from the other normally distributed cells which proceed to form the normal blood vascular pattern. This concept assumes a congenital origin for hemangiomas, an assumption which is in keeping with the fact that vascular tumors of the mediastinum are more frequently encountered in children than in adults.[2] Only one-fourth of the reported cases of hemangiomas of the mediastinum occurred in children, however. It is quite conceivable that many of the cases in adults would have been uncovered at an earlier age had thoracic roentgenograms been made sooner.

It is tempting to relate hemangiomas to teratomas of the mediastinum. Both neoplasms occur primarily in the anterior mediastinum. The second case of Schlumberger[7] (Case 7) lends some support to this concept. A hemangioma was removed from the anterior mediastinum of an asymptomatic 19-year-old man one year before a malignant teratoma was removed from the same location. Another vascular tumor associated with a mediastinal teratoma has been reported by Ehrenreich and associates.[21] However, careful histologic sampling of the two mediastinal hemangiomas in the files of the Clinic, the one reported here and that of Seybold and associates,[3] fails to support a teratomatous origin of these tumors.

The histologic appearance in the reported cases of mediastinal hemangiomas varies from that of a simple hemangioma composed of encapsulated blood vessels to a more complex picture. Varying amounts of smooth muscle, fibrous tissue, fat, and even bone are present in some cases. Stout[22] has classified such tumors as mesenchymomas and has stated that they are probably initiated as a result of developmental faults and can be regarded as dysontogenetic growths.

Treatment.—Surgical removal is, of course, indicated in all cases of mediastinal hemangioma, since it is unlikely that a correct preoperative diagnosis can be made. In 14 of the 19 cases, exploratory thoracotomy was performed. In 10 of these 14 cases, the tumor was completely removed without difficulty.

In four cases the tumor was locally invasive and was either incompletely removed or only biopsied. All four patients were alive and well at the time of the report seven months to four years postoperatively. Three of the four received roentgen therapy but in only one did thoracic roentgenograms reveal disappearance of the tumor. No change was noted in the size of the tumor on

thoracic roentgenograms in two cases. In addition to these four cases, in two cases reported by Bergstrom the tumors were locally invasive, making a total of six locally invasive hemangiomas of the mediastinum out of 19 reported cases.

The value of roentgen therapy in such cases is questionable. In only one case in which it was employed did the mass disappear on subsequent thoracic roentgenograms.

SUMMARY

A case is reported in which a hemangioma of the mediastinum in a 9-year-old boy was successfully removed at thoracotomy.

A total of 19 cases of mediastinal hemangioma have been reported. These tumors are commonly located in the anterior mediastinum and should be considered in the differential diagnosis of anterior mediastinal tumors.

Complete surgical removal is usually possible but in a significant number of cases the tumor may be locally invasive even though it is a benign tumor that does not metastasize.

REFERENCES

1. Watson, W. L., and Diamond, H. D.: Surgical Thoracic Tumors in Navy Personnel, J. THORACIC SURG. **16**: 1-11, 1947.
2. Ellis, F. H., Jr., Kirklin, J. W., Hodgson, J. R., Woolner, L. B., and DuShane, J. W.: Surgical Implications of the Mediastinal Shadow in Thoracic Roentgenograms of Infants and Children, Surg., Gynec. & Obst. **100**: 532-542, 1955.
3. Seybold, W. D., McDonald, J. R., Clagett, O. T., and Harrington, S. W.: Mediastinal Tumors of Blood Vascular Origin, J. THORACIC SURG. **18**: 503-517, 1949.
4. Adams, W. E., and Bloch, R. G.: Hemangioma of the Mediastinum: Report of a Case, Arch. Surg. **48**: 126-129, 1944.
5. Bergstrom, V. W.: Hemangioma of the Mediastinum Causing Death in the Newborn, New York J. Med. **45**: 1867-1871, 1945.
6. Thomas, N. K., and Chesser, I. M.: Cavernous Hemangioma of the Mediastinum: Case Report, J. THORACIC SURG. **20**: 321-324, 1950.
7. Schlumberger, H. G.: Atlas of Tumor Pathology. Tumors of the Mediastinum, Washington, D. C., 1951, National Research Council, Section V, Fascicle 18, pp. 41, 43, 68, 69.
8. Maggi, A. L. C., Barousse, A. P., and Cardeza, A. F.: Hemangioendotelioma de mediastino, Prensa méd. argent. **39**: 1438-1443, 1952.
9. Sebestény, J.: Über einige seltenere Mediastinaltumoren, Zentralbl. Chir. **78** (Part 2): 1425-1437, 1953.
10. Grimes, O. F., Raphael, R. L., and Stephens, H. B.: Cavernous Hemangioma of the Posterior Mediastinum: Case Report, J. THORACIC SURG. **25**: 324-326, 1953.
11. Maurer, E. R.: Cavernous Hemangioma of the Mediastinum: Report of a Case, Surgery **33**: 556-561, 1953.
12. Valle, A. R.: Hemangioma of the Mediastinum, Ann. Surg. **140**: 771-773, 1954.
13. Horst, J. V., and Beatty, O. A.: Mediastinal Hemangiofibroma: Case Report, Ohio M. J. **47**: 138, 1951.
14. Tal'man, I. M.: Surgical Excision of Hemangioma of the Posterior Mediastinum, Vestnik khir. **73** (#6): 50-52, 1953.
15. Keegan, J. M.: Hemangioma of the Mediastinum: Case Report, Am. J. Roentgenol. **69**: 66-68, 1953.
16. Emery, J. L., and Doxiadis, S. A.: Cavernous Angioma of the Mediastinum in a Child, Brit. J. Surg. **40**: 514-515, 1953.
17. Gross, R. E.: The Surgery of Infancy and Childhood: Its Principles and Techniques, Philadelphia, 1953, W. B. Saunders Company, pp. 779-780.
18. Schorr, S., Braun, K., and Isaac, G.: Mediastinal Tumour Containing Phleboliths, Brit. J. Radiol. n.s. **27**: 305-306, 1954.
19. Döderlein, Hugo: Ueber ein selten ausgedehntes Hämangiom des Zwerchfells sowie der inneren Brustund Bauchwand als Todesursache bei einem Neugeborenen, Zentralbl. allg. Path. **71**: 193-201, 1938.
20. Greenberg, Morris, and Angrist, Alfred: Primary Vascular Tumors of the Pericardium: A Report of Two Cases, Am. Heart J. **35**: 623-634, 1948.
21. Ehrenreich, Theodore, Freund, A. J., and Shapiro, H. N.: Hemangio-Endothelioma Arising in a Mediastinal Teratoma, Dis. Chest **23**: 294-303, 1953.
22. Stout, A. P.: Mesenchymoma, the Mixed Tumor of Mesenchymal Derivatives, Ann. Surg. **127**: 278-290, 1948.

SUBCARINAL MEDIASTINAL GRANULOMAS CAUSING ESOPHAGEAL OBSTRUCTION

JOSEPH J. GARAMELLA, M.D.,* FRANCIS L. STUTZMAN, M.D.,
RICHARD L. VARCO, M.D., AND NATHAN K. JENSEN, M.D.
MINNEAPOLIS, MINN.

DURING the past twelve years, reports of granulomatous lesions of the mediastinum have appeared with increasing frequency pointing to their surgical significance in the differential diagnosis and management of mediastinal tumors. It is the purpose of this paper to report 3 cases of subcarinal mediastinal granulomas causing obstructive esophagopathy, an uncommon clinical entity.

CASE REPORTS

CASE 1.—V. A. H., Minneapolis, Minnesota, No. 154-170. The patient was a 24-year-old white male student who was well until March 5, 1954, at which time he noted a rubbing sensation in the right chest anteriorly associated with a nonproductive cough. Four days later he experienced right chest pain and dysphagia. Solid foods were more troublesome than liquids. His cough became productive of clear, thin material. A temperature of 102° F. gradually subsided during a seven-day interval.

At a neighboring clinic, a barium swallow showed narrowing in the mid-portion of the esophagus as by extrinsic pressure, and bronchoscopy showed an area of ulceration in the right main-stem bronchus. Esophagoscopy showed no intraluminal pathology. Skin tests for tuberculosis and fungi were reported negative. Esophageal dilatations were performed and the dysphagia subsided. His appetite improved and he regained most of a 10-pound weight loss incurred since the onset of his illness. In the middle of May, right chest pain and dysphagia recurred, although not as severely as during the initial episode. Chest pain was aggravated by deep breathing or hard work. He was hospitalized on June 1, 1954.

Past History.—The patient admitted having had German measles, whooping cough, and frequent colds as a child. A tonsillectomy was performed in 1941. A traumatic circumcision was sustained in 1942. Pneumonia occurred in 1951.

Family History.—Noncontributory.

Systemic Review.—The patient admitted to easy fatigue. There was a sensitivity reaction to tetanus toxoid.

Physical Examination.—The patient was well developed and well nourished and did not appear ill. Temperature, 98.6° F.; pulse, 68; blood pressure, 106/66 mm. Hg; height 5 feet 9 inches; weight, 135 pounds. Complete examination revealed only "shotty" cervical nodes bilaterally.

Laboratory Data.—The hemoglobin was 13.9 Gm.; white blood count, 6,400; normal differential count; sedimentation rate, 42 mm. in one hour; and urinalysis normal. The tuberculin skin test with purified protein derivative first strength was one plus. Histoplasmin skin test was two plus. Coccidioidin and Frei tests were negative. Sputum examinations for acid-fast bacilli were negative as were cultures and guinea pig inoculations. X-ray of the chest showed mottled calcifications and an ill-defined mass in the subcarinal area (Fig. 1). An esophagram showed definite narrowing for approximately 6 cm. just below the carina

From the Thoracic Surgical Services, Veterans Administration Hospital and University of Minnesota Hospitals, Minneapolis, Minn.

Received for publication Jan. 27, 1955.

*Presently at the Jay C. Phillips Research Laboratory, Mount Sinai Hospital, Minneapolis, Minn.

Fig. 1.—Case 1. Lateral planigram showing ill-defined mass in subcarinal area. Mottled calcification not readily apparent in photograph but seen in x-ray. (Aug. 30, 1954.)

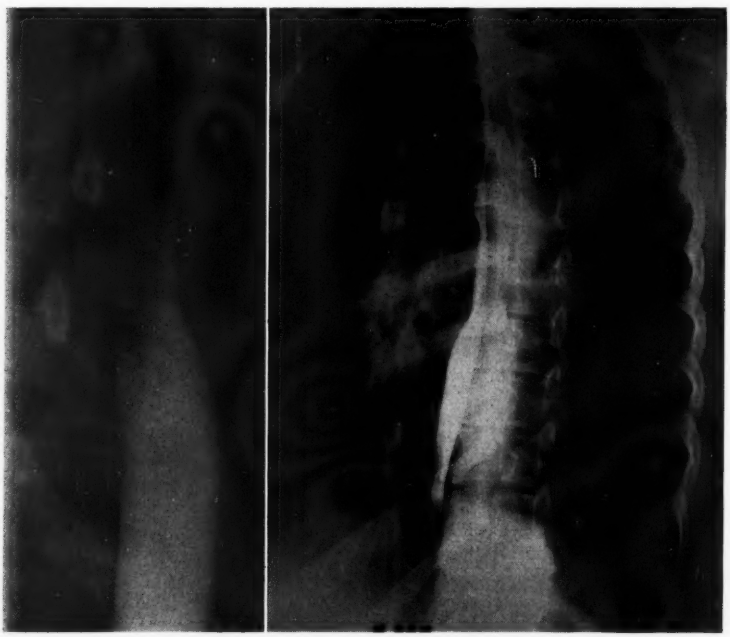


Fig. 2. Fig. 3.

Fig. 2.—Case 1. Left anterior oblique projection. Barium swallow showing narrowing of the mid-esophagus at subcarinal level. (June 3, 1953.)

Fig. 3.—Case 1. Barium swallow, spot film, showing esophageal defect. (Aug. 26, 1954.)

(Figs. 2 and 3). There was, however, no obstruction to the flow of barium seen during fluoroscopic study. Bronchoscopy performed on June 15, 1954, showed broadening of the carinal area and absence of the carinal spur. On the medial aspect of the right main-stem bronchus there was a protuberant granulomatous mass 2 by 2 mm. which bled easily on contact and from which exuded a thread of thick, creamy material. The left main-stem bronchus was partially narrowed as by extrinsic pressure. The mucosa was thick, shiny, and deeply reddened.

Washings of the bronchi submitted for acid-fast bacilli and fungi proved negative. A biopsy of the mucosa in the carinal area showed subacute and chronic inflammation with several multinucleated giant cells of the Langhans type. There was no necrosis and epithelioid cell granulomas were absent.

Hospital Course.—With the foregoing data, it was felt that this patient had partial esophageal obstruction due to the enlargement of subcarinal lymph nodes. Since tuberculosis was considered as a strong possibility in the differential diagnosis, despite the lack of bacteriologic confirmation, chemotherapy was started on June 30, 1954, consisting of streptomycin, 1 Gm., twice weekly, and para-aminosalicylic acid, 12 Gm., daily. A broncholith was coughed up during the hospital stay.

Early in July, the patient's dysphagia disappeared. On Sept. 10, 1954, bronchoscopy was repeated showing the carina to be sharp and clean. The ulcerated area in the right main-stem bronchus was still present but was no longer friable or draining. The inflammatory changes in the left main-stem bronchus were less marked.

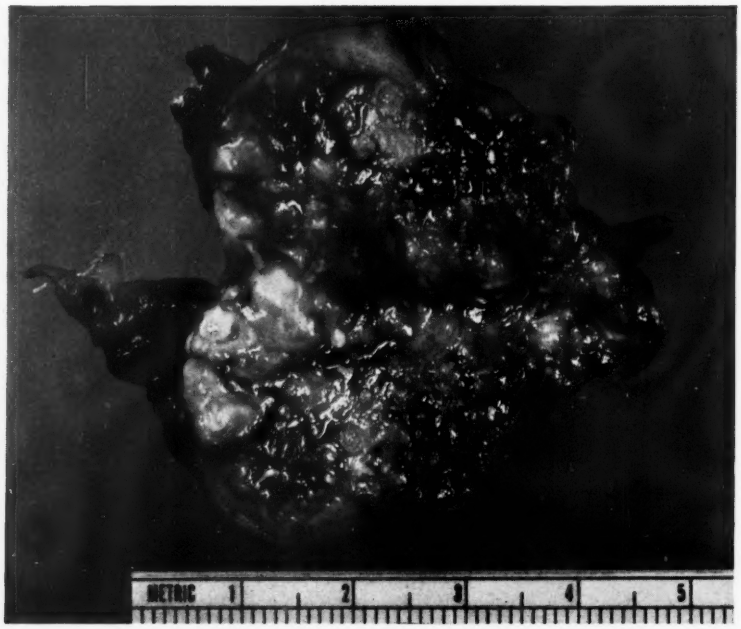
Because of the persistent bronchoscopic changes suggesting a chronic, smoldering inflammatory process and because of the inability to rule out other mediastinal lesions, thoracotomy was elected.

Operative Report.—Right thoracotomy was performed on Sept. 6, 1954, in the lateral position through the bed of the sixth rib. The pleural space was free. There was some scarring of the apical pleura but the lung was otherwise free of palpable disease. There was a firm mass approximately 6 cm. in largest diameter in the subcarinal area, grossly resembling chronically inflamed lymph nodes. The mass was densely adherent to the right and left main-stem bronchi, to the pericardium and esophagus, compressing the right side of the latter. Several peribronchial and inferior mediastinal lymph nodes were noted and were not remarkable.

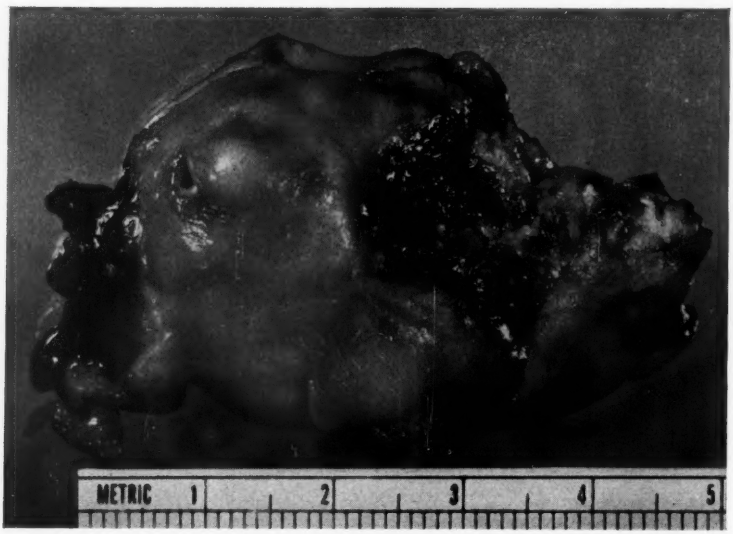
The mediastinal pleura above and below the subcarinal mass was raised allowing mobilization of the esophagus and thus better orientation of the relation of the tumor to the surrounding structures. The mass was then sharply dissected from its attachment to the right main-stem bronchus, revealing a granular area on the inferior margin approximately 1 cm. in diameter suggesting the site of ulceration and eruption into the right main-stem bronchus. In similar fashion, the mass was excised from its attachments to the pericardium, left main-stem bronchus, and esophagus. In one area of the esophagus, the submucosa was bared requiring reconstruction of the muscularis. A frozen section examination of the resected specimen confirmed the inflammatory nature. The chest was closed with drainage. The postoperative course was uneventful. The patient had no dysphagia three months postoperatively.

Pathologic Report.—Gross appearance (Fig. 4, *A* and *B*): The specimen consisted of a mass of tissue which measured 6.5 by 4 by 2 cm. It was slightly irregular and had a smooth fibrous surface except in one area where there was a groove measuring 3 by 2 cm. with a rough hemorrhagic base in which there were studded many fine white dots. On cut surface, the mass had a fibrous capsule from which there were numerous fibrous trabeculae coursing through the interior and between which were small areas of soft, tan tissue, and nodules consisting of pale, yellowish-white, pasty material measuring 8 mm. in greatest diameter. *Microscopic examination* (Fig. 5, *A* and *B*): The mass consisted of a fibrous and lymphatic tissue background in which there were numerous epithelioid granulomas, many of which contained necrotic centers and numerous multinucleated giant cells. A multinucleated cell was present which contained a Schaumann's body. Foci of calcification were also noted. Acid-fast and fungus stains failed to reveal any organisms.

Diagnosis.—Granulomatous inflammation of the mediastinal lymph nodes, probably tuberculosis.



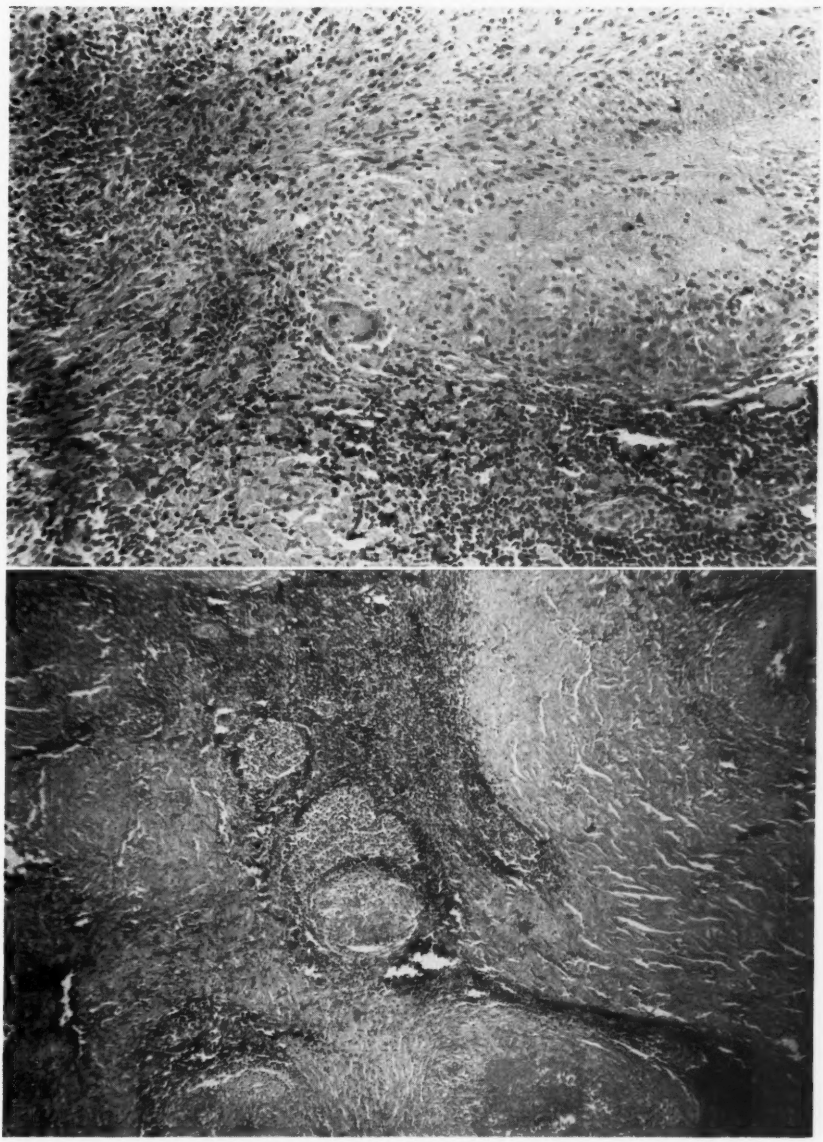
A.



B.

Fig. 4.—Case 1. *A*, Gross specimen as removed. *B*, Gross specimen in cross section.

A.



B.

Fig. 5.—Case 1. *A*, Photomicrograph showing a large granuloma with a caseous center and epithelioid zone present in the right upper quadrant. Multinucleated Langhans-type giant cells are noted on the periphery of the granuloma. (×100; reduced ¼.) *B*, Photomicrograph showing multiple epithelioid granulomas with central areas of necrosis. Large zones of fibrosis are apparent. (×36; reduced ¼.)

CASE 2.—St. Mary's Hospital, Minneapolis, Minnesota, No. 218144. A 39-year-old white housewife was hospitalized on March 25, 1954, complaining of dysphagia of ten weeks' duration commencing with liquids and progressing to solid foods. She also noted weakness and frequent regurgitation. For one week she experienced severe odynophagia and regurgitated all ingested food. Forty-eight hours prior to admission she refused all foods.

Past History.—Hypothyroidism followed a thyroidectomy done in 1948. Appendectomy and bilateral tubal ligation were previously performed.

Family History.—Diabetes mellitus and tuberculosis were elicited.

Systemic Review.—Noncontributory.

Physical Examination.—The temperature was 98.6° F.; pulse 76; blood pressure, 120/70 mm. Hg. The patient was well developed, well nourished, and appeared in a mild state of anxiety. The general physical examination was otherwise not remarkable.

Fig. 6.—Case 2. Right anterior oblique projection. Barium swallow showing filling defect of esophagus in the mid-portion suggesting an extrinsic lesion. (April 23, 1954.)

Laboratory Data.—The urinalysis was negative; hemoglobin, 11.4 Gm.; white blood count 8,100. Routine x-ray of the chest was negative. A barium swallow showed a filling defect of the esophagus in the mid-portion suggesting an extrinsic lesion (Fig. 6).

Hospital Course.—Esophagoscopy failed to reveal an intrinsic lesion. There was definite fullness on the posterior wall of the esophagus, 27 cm. from the incisor teeth. An extrinsic tumor mass was noted on the posterior and right lateral wall. The esophagoscope was not advanced beyond the tumor level. Aspiration studies for tumor cells and acid-fast organisms were negative. On March 26, 1954, thoracotomy was performed.

Operative Report.—The right pleural space was free. In the tip of the middle lobe anteriorly, there was a "shotty" area of granulomatous infiltration characteristic of old stabilized tuberculosis. The pleura was adherent to the tumor which was palpable between the right main bronchus and the esophagus and extended down along the posterior aspect of the intermediate bronchus. The lower pole of the tumor penetrated the esophageal wall and

was also densely adherent to the vagus nerve, bronchus, and surrounding structures. Frozen section study of a portion of the mass disclosed inflammatory changes. The tumor was dissected from the esophagus, the muscularis being removed to the submucosa. Many pockets of purulent material were encountered in the granulomatous tumor mass. These were aspirated and reserved for culture and microscopic examination. The muscular defect in the esophagus was repaired. The infiltration in the tip of the middle lobe was removed by clamp resection and the chest was closed with catheter drainage.

Pathologic Report.—Gross appearance: The specimen consisted of three lymph nodes, the largest of which measured 5 by 2.5 by 2.5 cm. On gross examination there were numerous areas of yellowish necrosis. A segment of pulmonary parenchyma measuring 3 by 2 by 1 cm. showed on gross examination multiple areas of necrosis up to 1.5 cm. in diameter. *Microscopic examination* (Fig. 7): Sections of the lung and lymph nodes revealed the presence of large and small granulomas. The smaller ones were composed entirely of epithelioid cells and the larger ones showed central necrosis. There were also noted scattered Langhans-type giant cells. Stains for acid-fast organisms were negative. Cultural studies for acid-fast organisms and fungi were negative.

Fig. 7.—Case 2. Photomicrograph showing multiple granulomas with central necrosis surrounded by palisaded histiocytes and epithelioid cells. (×36; reduced ¼.)

Diagnosis.—Pulmonary and lymph node granulomas of undetermined etiology.

Postoperative Course.—The immediate convalescence was uneventful. Because of the indeterminate nature of the lesion and the possibility of tuberculosis, PAS and streptomycin were administered. Four months postoperatively the patient had no dysphagia. One month later she was nervous and was having tightness on swallowing. Three dilatations were performed. Six months postoperatively, on the last visit, there was no dysphagia but she complained of pain in the epigastrium about ten minutes after eating.

CASE 3.—University of Minnesota Hospital, No. 851804. The patient was a 25-year-old male physician who was well until April 7, 1953, when he developed a sore throat. He treated himself with Aureomycin and a 250 mg. Aureomycin capsule lodged in his esophagus. He felt as though his esophagus went into spasm. Subsequently for thirteen days he had no

further dysphagia but did experience slight odynophagia especially if his food was lumpy. On April 20, 1953, a piece of beefsteak stuck in his esophagus and he subjectively localized the obstruction near the mid-esophagus. A similar episode occurred on April 24, 1953, and during the night of April 26, 1953, he was awakened with spasmodic esophageal pain. He consulted his physician on April 27, 1953.

Past History.—The patient had frequent episodes of severe sore throat with *Streptococcus viridans* as the causative organism. His tonsils had been hypertrophic since early childhood.

Family History.—Noncontributory.

Systemic Review.—Noncontributory.

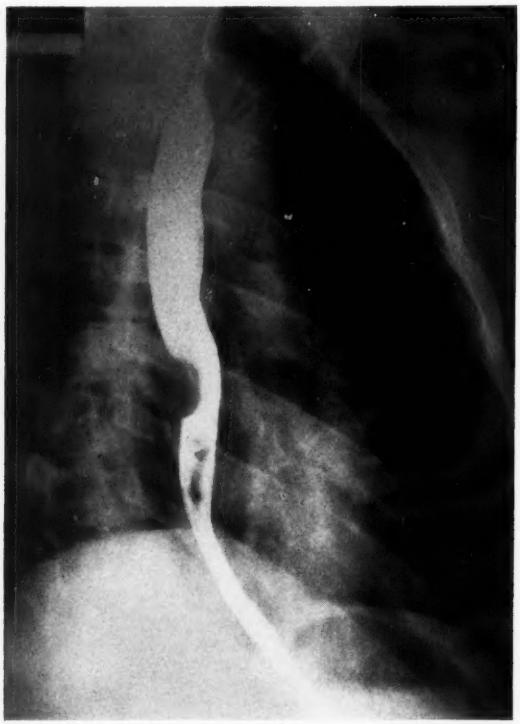


Fig. 8.—Case 3. Right anterior oblique projection. Barium swallow showing esophageal defect and displacement of the esophagus to the left.

Physical Examination.—The patient was a well-developed, well-nourished individual who showed no evidence of chronic illness. The temperature was 100° F.; pulse 88; and blood pressure, 135/80. The only gross abnormal physical finding was the presence of large, soft, furrowed tonsils which were inflamed.

Laboratory Data.—The hemoglobin was 14.1 Gm.; white blood count 9,850, neutrophils 83 per cent, lymphocytes 14 per cent, monocytes, 3 per cent. The sedimentation rate was 73 mm. in one hour. The urinalysis was normal. Tuberculin skin test with second strength PPD was negative. Sputum studies for acid-fast bacilli were negative. Histoplasmin skin test 1:1,000 was negative. Peripheral blood smear showed no evidence of leukemia. Roentgenologic examination of the chest in the posteroanterior position showed a mass in the mid-mediastinal area extending to the right side. The mass was of indeterminate character, and on lateral projection the mass occupied the middle of the posterior mediastinum.

An esophagram revealed a large mass attached to the right posterior portion of the esophagus, displacing the esophagus to the left. It appeared to be extraluminal but intramural (Fig. 8).

A preoperative diagnosis of intramural esophageal mass, either leiomyosarcoma or leiomyoma, was made.

Operative Report.—On May 1, 1953, right thoracotomy was performed in the lateral position through the bed of the fifth rib. The pleural space was free. There was no palpable disease in the lung parenchyma. A firm mass, 7 by 5 by 3.5 cm., was present in the subcarinal area displacing the esophagus and right lower lobe bronchus. The esophagus and right lower lobe bronchus were bent over this tumor. The mass was excised from these structures to which it was adherent. The chest was closed with drainage.

Pathologic Report.—Gross appearance: The specimen was an irregular mass of firm tissue 7 by 5.7 by 3.5 cm. which seemed to consist of enlarged lymph nodes. On sectioning, large areas of grayish, white, caseous material measuring up to 1.5 cm. were noted.

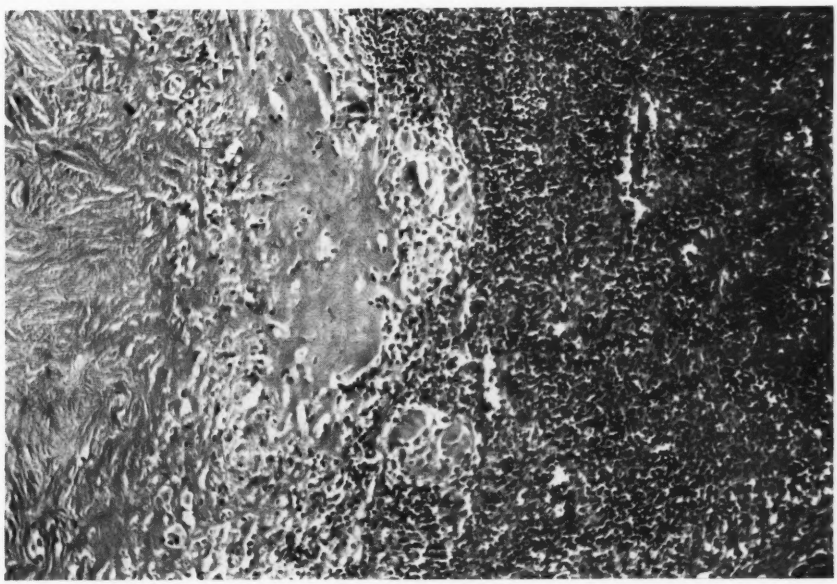


Fig. 9.—Photomicrograph showing in the left half of the field a large area of fibrosis with bordering small epithelioid granulomas. The right half of the field shows lymph node architecture. (×100; reduced ¼.)

Microscopic Appearance.—(Fig. 9.) Microscopically, portions of lymph nodes were seen with large areas of necrotic, granular, pink-staining material surrounded by epithelioid cells and a few multinucleated giant cells. Many polymorphonuclear and mononuclear inflammatory cells were seen. The surrounding tissue showed an increased amount of fibrous tissue and carbon pigment. Some calcific material was present in necrotic areas. No tubercle bacilli were seen with special staining techniques. The appearance of the specimen was compatible with tuberculosis or similar granulomatous processes.

Diagnosis.—Chronic granulomatous inflammation of mediastinal lymph nodes.

Postoperative Course.—Postoperatively the patient developed partial atelectasis of the right lung which cleared with intratracheal suctioning. Eighteen months postoperatively there were no esophageal symptoms.

TABLE I

CASE NO.	REPORTED BY	AGE	SEX	SYMPTOMS	MEDIASTINAL LOCATION	TUBERCULIN SKIN TEST	OTHER SKIN TESTS	PREOPERATIVE DIAGNOSIS	ACID-FAST BACILLI
1	Grace[4]	32	F	Dyspnea, pain, cough	Left anterior superior hilar	Positive	Not reported	Dermoid	None
2	Blades and Dugan[5]	56	M	Dyspnea	Right posterior inferior	Not reported	Not reported	Neurogenic tumor	Acid-fast rare
3	Tjamouranis[6]	5	F	Dyspnea, cough, stridor	Right superior	Positive	Casoni, negative	Tuberculoma	None
4	Paulson[7]	33	M	None	Right posterior superior	Positive	Not reported	Mediastinal tumor	None
5	Paulson[7]	21	M	None	Right posterior superior	Positive	Not reported	Mediastinal tumor	None
6	Perasälo[8]	16	F	Tiredness, weakness, anemia, vague pressure	Right posterior superior	Positive	Not reported	Mediastinal cyst	Not reported
7	Case report, M. G. H. 1945[9]	43	F	Substernal pain, dysphagia	Level of carina	Not reported	Not reported	Carcinoma, esophagus	Not reported
8	Samson, Heaton, and Dugan[10]	27	F	Dysphagia	Right posterior superior	Not done	Not done	Dermoid	None
9	Samson, Heaton, and Dugan[10]	19	M	None	Left anterior superior	Negative	Coccidioidin, negative	Dermoid	None
10	Samson, Heaton, and Dugan[10]	22	M	Dyspnea, cough	Left anterior superior	Not done	Not done	Bronchogenic cyst	None

11	Samson, Heaton, and Dugan[10]	34	F	Severe cough, dyspnea	Right posterior superior	Positive	Coccidioidin, negative; histoplasmin, positive	Mediastinal tumor ? aneurysm	None
12	Samson and Dugan[11]	29	F	Pain, dysphagia, odynophagia	Subcarinal	Not reported	Not reported	Hiatus hernia	Few on direct smear
13	Goldman[12]	Not reported			Bifurcation of trachea	Negative	Coccidioidin, negative	Carcinoma esophagus	Not reported
14	Woodruff[13]	60	M	Not reported	Bifurcation of trachea	Not reported	Not reported	Not reported	Not reported
15	Storey and Lyons[14]	24	M	None	Right superior	Positive	Negative	Not reported	Present
16	Storey and Lyons[14]	20	M	None	Anterior cardiophrenic angle	Negative	Not reported	Echinococcus cyst, pericardial cyst, atelectasis	None
17	Storey and Lyons[14]	25	M	None	Right posterior	Negative	Negative	Tuberculoma	Present
18	Storey and Lyons[14]	20	M	Headache, malaise, anorexia, cough, expectoration	Right superior	Negative	Negative	Tuberculoma	None
19	Storey and Lyons[14]	30	M	Pain in shoulder, arm, chest, venous obstruction	Right superior	Positive	Negative	Boeck's sarcoid, Hodgkin's disease, tuberculosis, lymphoblastoma	None
20	Rapant and Dvoracek[15]	19	M	Paravertebra, interscapular pain, cough	Posterior superior mediastinum	Negative	Not done	Neurogenic tumor	None

TABLE I—CONT'D

CASE NO.	REPORTED BY	AGE	SEX	SYMPTOMS	MEDIASTINAL LOCATION	TUBERCULIN SKIN TEST	OTHER SKIN TESTS	PREOPERATIVE DIAGNOSIS	ACID-FAST BACILLI
21-36	Kunkel, Clagett, and McDonald[16] (16 cases)	2-59 years	8 M 8 F	10 Asymptomatic referable to chest 3 Minimal symptons (Above 13 cases noted on routine x-ray of chest) 1 Pleuritic pain, fever, weight loss 1 Fever, substernal heaviness, dyspnea 1 Wheezing, cough, fever	13 Right paratracheal 1 Paratracheal, bilaterally 1 Left hilus 1 Left posterior inferior	6 Negative 2 Positive	3 Negative	Not given for individual cases Differential diagnosis included: Granuloma Thymoma Dermoid cyst Enterogenous cyst Thyroid adenoma Lymphoma Neurogenic tumor Aneurysm Other rare conditions	12 smears, negative 13 guinea pigs and cultures, negative
37	Authors	24	M	Chest pain, cough, fever, dysphagia	Subcarinal	Positive	Negative	Mediastinal granuloma	None
38	Authors	39	F	Severe dysphagia, odynophagia, regurgitation	Subcarinal	Not done	Not done	Esophageal tumor, stricture	None
39	Authors	25	M	Sore throat, dysphagia, odynophagia	Subcarinal	Negative	Histoplasmin, negative	Intramural tumor of esophagus	None

DISCUSSION

Piazzi-Martinni[1] described cases of mediastinal tuberculoma and gumma. Haines[2] recognized the development of mediastinal tumefaction due to lymph node enlargement in the course of systemic tuberculosis or syphilis and also mentioned the necessity of differentiating these tumors from other new growths. Grow[3] and his associates reported 8 cases of "tuberculous lymphadenopathy" in 73 cases explored for mediastinal lesions. Additional details were lacking. Grace[4] is credited with the first surgical extirpation of a mediastinal granuloma and others have since reported cases treated surgically. These are summarized in tabular form (Table I).

Analysis from the available information in the 39 collected cases surgically treated including 3 of this report reveals the following data (Table II).

Other similar cases not treated by surgical excision have been reported by Perasälo[8] and Storey.[14] Paulson[7] commented on 2 additional cases under ob-

TABLE II

Age:	2-60 years
Sex:	16 females 22 males 1 not recorded
Symptoms:	16 asymptomatic 6 dyspnea 8 cough 7 chest pain 6 dysphagia 3 odynophagia 4 fever 4 others 2 not reported
Mediastinal location:	19 right posterior superior 5 right superior 1 right posterior inferior 3 left anterior superior 1 left posterior inferior 1 right and left superior posterior 1 left hilus 1 anterior cardiophrenic angle 1 level of carina 6 subcarinal
Tuberculin skin test:	11 positive 13 negative 3 not done 12 not reported
Other skin tests:	12 negative 1 positive 4 not done 22 not reported
Preoperative diagnosis:	2 correct 2 probably correct correct in others (cases 21-26) number correct not given
Acid-fast bacilli:	4 positive 28 negative 7 not reported

servation, 1 asymptomatic and 1 with dysphagia, both with presumptive diagnoses of tuberculoma. Frew[17] reported a case of esophageal and tracheal obstruction at the postcarinal level. Biopsy through intact esophageal mucosa showed a histologic pattern typical of tuberculosis. Bacteriologic confirmation was lacking. Clerf[18] reported a case of a 22-year-old seminarian with dysphagia and odynophagia. The esophagus was narrowed at the level of the aortic arch and displaced anteriorly. The mucosa was inflamed. Purulent drainage was promoted by instrumentation. Bacteriologic studies showed tubercle bacilli, a few pneumococci, and streptococci. The source of infection was presumed to be tuberculosis of the mediastinal nodes. Jacob[19] presented a case of a 28-year-old woman with esophageal obstruction at the level of the aortic arch. Acid-fast bacilli were recovered from a subclavicular node. Radiotherapy to the mediastinal nodes rendered a good result.

COMMENT

Although the etiology of practically all of these mediastinal lesions remains indeterminate with our present methods of investigation, the probable relation to tuberculosis warrants continued attention. This aspect of the problem is of more than academic interest in view of the beneficial effects of antimicrobial drug therapy in tuberculosis. In earlier reports of tuberculosis involving the esophagus, the process had advanced in most instances to the stage of ulceration, perforation, or fistulization with the trachea or bronchi. Denonnvilliers[20] reported the first case in 1837. Flexner[21] discussed the pathogenesis, emphasizing the different routes of infection. Lockhard[22] reviewed the literature and collected 103 cases, 69 of which could with reasonable certainty be classified as tuberculous. In his study, extension by continuity from caseous bronchial glands was by far the most frequent etiological factor accounting for 35 of 103 cases studied. Although the etiology of the cases herein reported by us has not been confirmed by bacteriologic studies, it is suggested that the location of the granulomatous lesions, the histopathologic characteristics, the resemblance to similar cases cited in which the bacteriologic studies confirmed the diagnosis of tuberculosis, are not coincidental. It is, nevertheless, agreed that the term tuberculoma should be reserved only for those cases in which specific acid-fast organisms are found.

Admittedly uncommon, at least 6 and probably 2 others (Cases 13 and 14) of the collected cases surgically treated, presented with symptoms referable to the esophagus and, therefore, mediastinal granulomas should be considered in the differential diagnosis of obstructive lesions of the esophagus. A sufficient number of granulomas have been reported to assign them a rightful niche in the classification of mediastinal tumefactions and they are therefore worthy of attention in managing indeterminate mediastinal lesions.

Although no particular technical surgical problems were encountered in the 3 cases reported, these have been mentioned by others (Samson and associates,[10] Storey,[14] Kunkel[16]), particularly in dealing with lesions related to large vessels. This is consonant with the character of the underlying pathology. The sequelae of tracheal, bronchial, and esophageal and vascular obstruction in given

instances establish mediastinal granulomas as potentially hazardous lesions. The serious consequences of mediastinal fibrosis presumably of granulomatous origin are well illustrated by a case cited by Kunkel[16] in which there was tracheal and bronchial obstruction and also by the fascinating case of Edwards and Burchell[23] in which the venous return from both lungs was completely occluded except for the right inferior pulmonary vein, with resultant pulmonary hypertension, ventricular failure, and death. It is felt that symptomatic and doubtful lesions present definite indications for surgery.

SUMMARY

1. Three uncommon cases of subcarinal mediastinal granulomas producing esophageal obstruction are presented.

2. Previously reported cases of mediastinal granulomas surgically treated are reviewed.

3. The etiology of most of these lesions remains challenging but the probable tuberculous origin demands continued special attention.

4. Symptomatic and doubtful lesions are definite indications for surgery.

REFERENCES

1. Piazzi-Martinni, V.: New Symptoms of Mediastinal Tumors, Ann. di clin. med. **5**: 173, 1914. Cited by Burnham, C. F.: New Growths of the Mediastinum, J. A. M. A. **69**: 989, 1917.
2. Haines, W. D.: Tumors of the Mediastinum, Surg., Gynec. & Obst. **20**: 542, 1915.
3. Grow, J. B., Bradford, M. D., and Mahon, H. W.: Exploratory Thoracotomy in the Management of Intrathoracic Disease, J. THORACIC SURG. **17**: 480, 1948.
4. Grace, A. J.: Tuberculoma of the Mediastinum, J. THORACIC SURG. **12**: 131, 1942.
5. Blades, B., and Dugan, D. J.: Tuberculoma of Posterior Mediastinum, Am. Rev. Tuberc. **50**: 41, 1944.
6. Tjamouranis, D.: Tuberculoma of the Mediastinum, Acta Soc. pediat. hellen. **2**: 70, 1948.
7. Paulson, D. L.: Discussion of paper by Samson, P. C., Heaton, L. D., and Dugan, D. J.: Mediastinal "Tuberculoma" Surgical Removal in Four Patients, J. THORACIC SURG. **19**: 333, 1950.
8. Perasälo, O.: Mediastinal "Tuberculoma," Ann. chir. et gynaec. Fenniae. **39**: 213, 1950.
9. Massachusetts General Hospital Case Report No. 31341: New England J. Med. **233**: 255, 1945.
10. Samson, P. C., Heaton, L. D., and Dugan, D. J.: Mediastinal "Tuberculoma." Surgical Removal in Four Patients, J. THORACIC SURG. **19**: 333, 1950.
11. Samson, P. C., and Dugan, D. J.: Unusual Causes of Dysphagia, Ann. Otol. Rhin. & Laryng. **60**: 738, 1951.
12. Goldman, A.: Discussion of paper by Samson, P. C., Heaton, L. D., and Dugan, D. J.: Mediastinal "Tuberculoma." Surgical Removal in Four Patients, J. THORACIC SURG. **19**: 333, 1950.
13. Woodruff, W.: Discussion of paper by Samson, P. C., Heaton, L. D., and Dugan, D. J.: Mediastinal "Tuberculoma." Surgical Removal in Four Patients, J. THORACIC SURG. **19**: 333, 1950.
14. Storey, C. F., and Lyons, H. A.: Tuberculomas of Mediastinum, Am. Rev. Tuberc. **64**: 327, 1951.
15. Rapant, V., and Dvoracek, C.: Tuberculoma Mediastina, Rozhl. chir. **30**: 47, 1951.
16. Kunkel, W. M., Clagett, O. T., and McDonald, J. R.: Mediastinal Granulomas, J. THORACIC SURG. **27**: 565, 1954.
17. Frew, I. J. C.: Tuberculosis of the Esophagus, J. Laryng. & Otol. **64**: 774, 1950.
18. Clerf, L. H.: Tuberculous Periesophageal Abscess Producing Stenosis. Report of a Case, Ann. Otol. Rhin. & Laryng. **49**: 793, 1940.
19. Jacob, P.: Adenopathie tracheobronchique de l'adulte determinant une compression oesophagienne, Rev. Tuber., Lima **6**: 305, 1941.
20. Denonnvilliers: Bull. Soc. Anat. 294, 1837.
21. Flexner, Simon: Tuberculosis of the Esophagus, Bull. Johns Hopkins Hosp. **4**: 4, 1893.
22. Lockhard, L. B.: Esophageal Tuberculosis; A Critical Review, Laryngoscope **23**: 561, 1913.
23. Edwards, J. E., and Burchell, H. B.: Multilobar Pulmonary Venous Obstruction With Pulmonary Hypertension: "Protective" Arterial Lesions in the Involved Lobes, Arch. Int. Med. **87**: 372, 1951.

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SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS IN AN ISOLATED SANATORIUM

A Five-Year Study of Trends and Results

A. L. Paine, M.D.
Ninette, Manitoba

INTRODUCTION

DURING the earlier days of this century when bed rest, fresh air, and seclusion rated high as treatment for tuberculosis, many sanatoriums were located in isolated areas. In keeping with this trend, Manitoba Sanatorium was built in scenic surroundings in 1909, about 150 miles from the chief medical and population center of the Province. With the widespread adoption of surgical collapse in the mid-thirties many such institutions met the problem of major chest surgery, either by sending their patients for operation to the nearest large center, or by having a consultant surgeon come in periodically to do the work. Less frequently the sanatorium setup a self-contained surgical unit with all operations performed by the resident medical staff. In support of this plan, Ross[1] in 1937 discussed the advantages of a sanatorium doing its own surgery; a policy which Manitoba Sanatorium adopted at that time and has adhered to ever since.

The plan succeeded well from the first. Meltzer,[2, 3, 4] who was resident surgeon from 1936 to 1941, published results in thoracoplasty and extrapleural paraffin plombage which compared very favorably with those obtained elsewhere. Since 1941, I, as resident surgeon, have performed all the operations on patients of this institution. The problems of a Sanatorium doing its own surgery have multiplied in recent years for this 280 bed hospital. Isolation is the prime obstacle. The universal nursing shortage, worse in a sanatorium because of tuberculophobia, is further accentuated by our distance from larger centers. At first, anesthesia gave no special concern, because in the collapse therapy era we used a local anesthetic for all chest wall operations. Later, with the increasing need of pulmonary resection, the lack of a resident anesthesiologist was a serious handicap, and necessitated bringing one in for each such operation. Early in 1953, the problem of anesthesia was solved by training one of our own staff and since then the use of resection has markedly increased.

At times we have seriously questioned the merit of keeping up our surgical service under existing difficulties. Nowadays, patients, as well as staff,

From The Manitoba Sanatorium, Ninette, Manitoba.
Received for publication Jan. 27, 1955.

tend to shun isolation with its fewer leaves and visits from families and friends. However, our very isolation has, paradoxically, been the best reason for continuing. An institution, if associated in the public mind with modern surgical treatment, will attract both patients and staff and partly offset the objections of isolation. In other matters we are well set up for surgery. Laboratory facilities are excellent; blood is immediately available in any quantity and without charge through the Provincial Red Cross. All surgical specimens are carefully dissected out by the surgeon following operation; smears are taken for direct examination for tubercle bacilli and for culture. The specimen is then photographed in color and sent away for gross and microscopic pathological examination.

These circumstances under which the surgery to be reported was done have been outlined to serve as a background for better appraisal of the methods used and results obtained. That the surgery was performed at the Sanatorium by a resident staff under a considerable handicap imposed by isolation may actually add interest to the series, and it is believed has not adversely affected the results of treatment herewith presented.

MATERIAL

A list of all major surgical operations done during the five-year study period from Jan. 1, 1949, to Jan. 1, 1954, is given in Table I. Numbers refer to how often the procedure was performed and not to individuals treated. In some instances, patients had more than one procedure on the same side, as in resection following failure of thoracoplasty; in other cases bilateral surgery was done. The thoracoplasty listing includes 8 operations to obliterate pleural space before or after resection, and 3 for treatment of empyema. Thus, Table I presents the total amount of surgery done in the five-year period, but does not lend itself to an analysis of results.

TABLE I. COMPLETE LIST OF SURGICAL PROBLEMS*

PROCEDURE	NUMBER OF TIMES USED
Thoracoplasty (completed operations, not stages)	141
Revision thoracoplasty	8
Extraperiosteal plombage	21
Pulmonary resection	89
Decortication	3
Cavernostomy	5
Extrapleural pneumothorax	1
TOTAL	268

*Manitoba Sanatorium Jan. 1, 1949, to Jan. 1, 1954.

For purposes of analysis, the study has been confined to 219 patients who received major surgical treatment of parenchymal disease only. Of these, 194 patients had unilateral surgery; 25 patients had bilateral surgery, 9 of whom had both sides operated upon during the five-year study period and 16 of whom had one side completed before the study began. All patients received some antibiotic therapy. The earlier cases often had only a few days of

streptomycin during operation, although a six weeks' course of 0.5 Gm. daily was not uncommon in 1949. Later, combined antibiotic therapy became routine practice with the treatment period steadily increasing.

DEFINITION OF TERMS

In classifying results of treatment, "negative sputum" means sputum negative to smear, concentrate, and culture of gastric contents. Patients taking discharge too soon to allow complete sputum testing are considered positive until proved otherwise by further sputum examination. "Primary conversion" refers to sputum rendered negative by the first surgical procedure and "secondary conversion" refers to sputum becoming negative after a further surgical procedure.

Postoperative deaths or complications are those occurring within sixty days of operation; those after this period are termed "late." The final date for evaluation of status was placed at July 1, 1954, thus giving a follow-up period of six months for all cases and a maximum follow-up of five and one-half years.

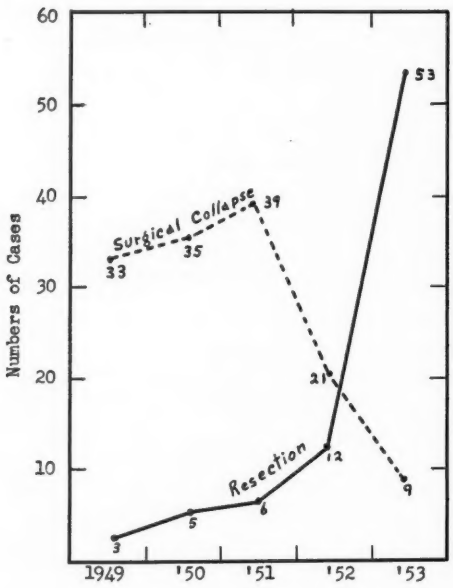


Fig. 1.

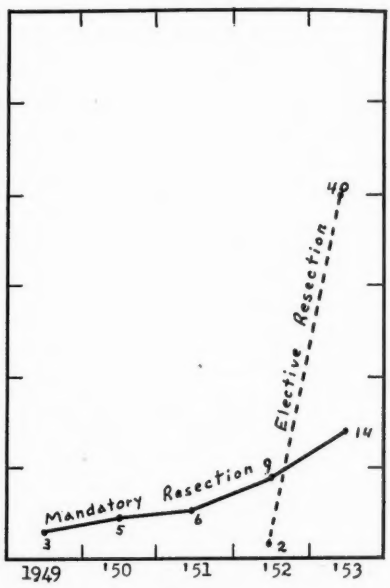


Fig. 2.

Fig. 1.—Graph showing the changing incidence of surgical collapse and pulmonary resection.

Fig. 2.—Graph showing the incidence of mandatory and elective resections.

Follow-up Classification.—Almost all patients after discharge obtain their periodic examinations by returning to the Sanatorium or attending stationary or travelling clinics operated by the Sanatorium Board. This gives greater

accuracy in roentgenographic interpretation and estimation of stability of disease than one could expect from reports of local physicians. Living patients are classified under four commonly accepted headings as follows:

1. Clinically well with negative sputum,
2. Positive sputum, or unstable roentgenogram (salvable cases),
3. Active or progressive disease or respiratory cripple (hopeless cases),
4. Inadequate follow-up—those where most recent report is before December, 1953, and/or less than six months postoperatively.

ANALYSIS

Unilateral Surgery.—As stated before, 194 patients had unilateral surgery; 137 received collapse therapy as a primary procedure, and of these, 22 also underwent resection before the end of the study period; in addition, 57 other patients in the unilateral group had resection which makes a total of 79 resections for analysis. The various procedures employed with their yearly incidence are shown in Table II. It will be seen that the number of patients with collapse therapy dropped from 33 in 1949 to 9 in 1953, while those treated by resection rose in the same period from 3 to 53. As elsewhere, antibiotic therapy is the chief factor in this reversal of incidence. However, the trend toward resection came later than usual in the present series due to the lack of resident anesthetic service in the early years of the study. In 1953, when this service was established, there was a marked upswing in resection surgery with a corresponding drop in collapse surgery as graphically illustrated in Fig. 1. A point of special interest is the increased use of apical, or 5 rib thoracoplasty toward the middle of the study period, as seen in Table II. Rapid clearing of disease with antibiotic therapy permitted the use of this less extensive thoracoplasty with increasing frequency. It was often applied as collapse treatment of residual foci in place of removal by resection, as we are now doing. Usually cavitation, if present, had been greatly reduced. Our interest in extraperiosteal pack did not develop until 1951, so the place of this procedure was partly taken by apical thoracoplasty.

TABLE II. UNILATERAL SURGERY 1949 TO 1953—216 CASES

PROCEDURE	NUMBER EACH YEAR					TOTAL
	1949	1950	1951	1952	1953	
Collapse Therapy						
Standard thoracoplasty	25	24	17	9	2	77
Apical thoracoplasty	6	10	13	7	3	39
Revision thoracoplasty	2	1	4	1	–	8
Extraperiosteal plombage	–	–	5	4	4	13
TOTAL	33	35	39	21	9	137
Resection						
Pneumonectomy	1	5	2	4	2	14
Lobectomy	2	0	4	5	8	19
Lobectomy plus	–	–	–	1	8	9
Other multiple resection	–	–	–	–	5	5
Wedge resection	–	–	–	–	22	22
Segmental resection	–	–	–	1	6	7
Lesionectomy	–	–	–	1	2	3
TOTAL	3	5	6	12	53	79

The use of further secondary surgery in the various collapse groups was as follows: of 77 patients with standard thoracoplasty, 14 had resection, and 2 cavernostomy; of 39 patients with apical thoracoplasty, 4 had resection, and 2 cavernostomy; 2 of the 13 patients with extraperiosteal pack had resection later, as did also 2 of 8 patients with revision thoracoplasty. Thus, of the whole group of 137 patients with unilateral surgical collapse, 22 ultimately had resection, and 4 cavernostomy.

As regards resection surgery, it will be noted in Table II that it was almost entirely confined to pneumonectomy and lobectomy during the first four years of the study period. During this period, resection was done mainly on thoracoplasty failures and only when no alternative collapse measure would suffice. The marked increase in resection in the last year of the study was due mainly to its more frequent use as an elective procedure as seen in Fig. 2.

Indications for unilateral resection are outlined in Tables III and IV. In 37 patients, resection was mandatory, according to commonly accepted treatment standards. These indications are listed in Table III and require no comment, except to point out that thoracoplasty failure was the most common.

TABLE III. INDICATIONS FOR UNILATERAL RESECTION, MANDATORY IN 37 CASES

Thoracoplasty failure	21
Endobronchial disease with stenosis atelectasis or sepsis	6
Bronchopleural fistula and empyema	1
Bilateral tuberculosis with low pulmonary reserve	3
Basal or hilar tuberculosis	5
Tuberculosis plus bronchiectasis	1
TOTAL	37

Also, it should be explained that the indication listed as "bilateral tuberculosis with low pulmonary reserve" refers to patients with bilateral lesions of such extent and location that surgical collapse was thought likely to encroach too much on pulmonary reserve. In these 3 cases, bilateral resection was thought to be necessary sooner or later. In 42 patients, resection was considered an "elective" procedure (Table IV). In all elective cases, disease was in the upper lung field and the patient had had antibiotic therapy for an average of six months. The treatment of the residual disease presented a problem on which there is, of course, no agreement at the present time. In some instances, such as those with open cavity and positive sputum, the need for surgery is granted but collapse could be used rather than resection. In other cases, as in noncavitary disease with negative sputum, the alternative treatment may be prolonged antibiotic therapy without surgery. Table IV attempts to list the various combinations of roentgenographic and sputum status found in the "elective" group and correlates these with the bacillary findings in the operative specimens. In Series I (8 cases) are patients with either open cavity or persistent positive sputum, or both, and who would commonly be considered for some form of surgery. In this group 87 per cent of the operative

specimens showed tubercle bacilli on smear and 37 per cent on culture. Series II (34 cases) consists of patients who originally had no roentgenographic evidence of cavity and no positive sputum, or with cavity closed and sputum converted by antibiotic treatment. Some of these patients might be considered suitable for prolonged antibiotic therapy without surgery, but all had residual foci considered "significant" and more than a centimeter in diameter. Also, the operative specimens all showed caseation with 62 per cent positive for tubercle bacilli to smear and 14 per cent to culture. Attention is called to the 10 cases in the noncavitary always negative group in Series II. Of these, 5, or 50 per cent, were tuberculomas; all showed tubercle bacilli on smear of the operative specimen; 2 were positive to culture.

TABLE IV. INDICATIONS FOR UNILATERAL RESECTION, ELECTIVE IN 42 CASES

	NUMBER	OPERATIVE SPECIMEN	
		SMEAR POS.	CULTURE POS.
SERIES I			
Preoperative Status			
Cavity open, sputum positive	5	5	2
Cavity open, sputum converted	1	1	0
Cavity closed, sputum positive	1	1	1
Noncavitary, sputum positive	1	0	0
TOTAL	8	7 (87%)	3 (37%)
SERIES II			
Preoperative Status			
Cavity closed, sputum converted	10	6	1
Noncavitary, sputum converted	14	9	2
Noncavitary, always negative	10	6	2
TOTAL	34	21 (62%)	5 (14%)

RESULTS IN UNILATERAL COLLAPSE THERAPY

All significant data are given in Table V which is self-explanatory, but some details are worth comment. The highest incidence of sputum conversion of those alive and well is in apical thoracoplasty. This is to be expected in view of the lesser extent of disease being treated. Even so, 6 of these 38 patients with final conversion became negative only by virtue of secondary operations.

The final conversion rate for the entire group of 137 with unilateral collapse was 84 per cent, of which 67 per cent came with the first operation and 17 per cent from secondary procedures. The incidence of tuberculous postoperative complications is believed to be unusually low. Only 3 patients (2.2 per cent) had a postoperative complication. Of these, 2 patients had a transitory cardiac decompensation with good recovery and 1 developed atelectasis requiring bronchoscopy before recovery. The absence of wound infections and postoperative spreads is worthy of note. Late complications occurred in 8 patients (6 per cent); in 3 of these a tuberculous tracheobronchitis ultimately developed considered to be aggravated by the collapse. Of the other 5, the late complication consisted of relapse after discharge in 4, and in 1 patient the disease continued to progress in spite of surgery.

TABLE V. RESULTS IN UNILATERAL SURGERY—COLLAPSE THERAPY

NUMBER OF CASES	THORACOPLASTY						EXTRA-PERIOSTEAL PACK		REVISION		TOTALS	
	STANDARD		APICAL		TOTAL							
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
	77		39		116		13		8		137	
Sputum conversion												
Primary	46	60	32	82	78	67	9	69	5	62	92	67
Secondary	13	17	6	15	19	16	2	15	2	25	23	17
Final	59	77	38	97	97	83	11	84	7	87	115	84
Tuberculous complications												
Post-operative	2	26	0		2	1.7	0		1	12.5	3	2.2
Late	7	26	1	2.5	8	7	0		0		8	6
Deaths												
Post-operative	0		0		0		0		0		0	
Late	7	9	0		7	6	0		0		7	5
Living (July, 1954)	70	91	39	100	109	94	13	100	8	100	130	95
Well with sputum negative	56	80	35	90	91	84	11	84	5	62.5	107	82
Salvable	6	8	2	5	8	7	1	8	1	12.5	10	8.5
Hopelessly ill	2	3	1	2.5	3	3	0		0		3	2
Inadequate follow-up	6	8	1	2.5	7	6	1	8	2	25	10	7.7

There were no postoperative deaths. Late deaths totalled 7 (5 per cent); of these, 2 were not from tuberculosis but from coronary disease two years after operation, and from myelogenous leukemia one year postoperatively. In the 5 late tuberculosis deaths, the causes were as follows: progressive disease in 3 cases, death after pulmonary resection in 2 cases (operation performed elsewhere in 1 of these).

As regards present status of the 137 patients treated with surgical collapse, 130, or 95 per cent, are living. Of the living, 107, or 82 per cent, are well with negative sputa; 10, or 8.5 per cent, are positive or have unstable lesions, but are considered salvable; 3, or 2 per cent, are hopelessly ill; 10, or 7.7 per cent, are alive but inadequately followed up.

RESULTS IN UNILATERAL RESECTION SURGERY

Seventy-nine patients had unilateral resection, as shown in Table VI. Postoperative complications for the 79 resection cases totalled 9, or 11 per cent. They occurred most commonly in the multiple resection group of which there were 5. Of these, 1 patient had a bronchopleural fistula and another a tuberculous wound infection. Both had been war prisoners with a poor nutritional background. Two patients had postoperative hemorrhage into the pleural space which required no surgical interference. One patient had an air leak which closed with complete re-expansion after a combination of

phrenic crush, pneumoperitoneum, and continuous suction. One patient with pneumonectomy had a wound infection with contralateral spread both of which eventually cleared completely; another had poor wound healing with a final good result. One patient with lobectomy had postoperative hemorrhage into the pleural space that was absorbed without active interference. In one wedge resection, poor healing occurred without infection and with a good final result. Thus, of the 9 postoperative complications, the last 7 listed cleared, leaving no disability. Late complications occurred in 4, or 5 per cent, of all patients. Two patients had stump ulcers with positive sputa following lobectomy. Both cleared completely on further antibiotic therapy. One patient after segmental and another after wedge resection had late ipsilateral spread, one of which has now cleared.

TABLE VI. RESULTS IN UNILATERAL SURGERY—PULMONARY RESECTION

	PNEUMONECTOMY	LOBECTOMY	LOBECTOMY PLUS OTHER RESECTION	OTHER MULTIPLE RESECTION	SEGMENTAL RESECTION	WEDGE RESECTION	LESIONECTOMY	TOTAL
NUMBER OF CASES	14	19	9	5	7	22	3	79
Sputum Conversion	13 (93%)	18 (95%)	8 (89%)	5 (100%)	6 (86%)	21 (95%)	3 (100%)	74 (94%)
Tuberculous Complications								
Postoperative	2 (15%)	1 (5%)	4 (44%)	1 (20%)	0	1 (5%)	0	9 (11%)
Late	0	2 (10%)	0	0	1 (14%)	1 (5%)	0	4 (5%)
Deaths								
Postoperative	1 (7%)	0	1 (11%)	0	0	0	0	2 (2.5%)
Late	0	0	1 (11%)	0	0	0	0	1 (1%)
Living (July, 1954)	13 (93%)	19 (100%)	7 (8%)	5 (100%)	7 (100%)	22 (100%)	3 (100%)	76 (96%)
Well with sputum negative	13 (100%)	18 (95%)	7 (100%)	5 (100%)	6 (86%)	21 (95%)	3 (100%)	73 (96%)
Salvable	0	0	0	0	1 (14%)	0	0	1 (1%)
Hopelessly ill	0	0	0	0	0	1 (5%)	0	1 (1%)
Follow-up inadequate	0	1 (5%)	0	0	0	0	0	1 (1%)

Postoperative deaths occurred in 2 patients (2.5 per cent). One which followed pneumonectomy was due to cardiorespiratory failure; the other, after multiple resection, was a result of the tuberculous wound infection quoted in the postoperative complications previously. Late death occurred in 1 patient and is listed under multiple resection. It was due to right-sided heart failure after a lower lobectomy done as treatment for a bronchopleural fistula arising from a previous multiple resection. Thus total deaths, including postoperative and late, were 3, or 3.8 per cent.

Summarizing, in 79 patients with unilateral pulmonary resection postoperative complications occurred in 9, or 11 per cent; late complication in 4, or 5 per cent. Nine of these 13 complications cleared with no residual disability. Death occurred in 3 cases, or 3.8 per cent, of which 2 were postoperative and 1 late. As regards present status, 76 patients (96 per cent) are living; of these 96 per cent are well with negative sputum, 1 per cent salvable, 1 per cent hopelessly ill, and 1 per cent untraced.

Of special interest is the thoracoplasty failure group comprising 21 patients of whom 1 died postoperatively and the remaining 20, or 95 per cent, are now well with negative sputum.

Bilateral Surgery.—Twenty-five patients had bilateral surgery, but it should be pointed out that in 17 of these the surgery on one side had been done before the five-year study period. The various combinations of bilateral surgery are shown in Table VII. It will be noted that the commonest procedure was thoracoplasty. It was most frequently combined with plombage which was extrapleural in 5 patients and extraperiosteal in 7. Bilateral thoracoplasty was performed in 4 patients, and bilateral resection in 3. The incidence of other combinations was as follows: extrapleural-extraperiosteal plombage, 1; thoracoplasty-extrapleural pneumothorax, 1; thoracoplasty resection, 2; thoracoplasty-cavernostomy, 2. In 5 patients with bilateral surgery, further secondary operations were done as follows: resection, 2; cavernostomy, 2; revision, 1.

TABLE VII. BILATERAL SURGERY 1949 TO 1953—25 CASES

TYPE	BOTH SIDES DURING 1949 TO 1953	ONE SIDE BEFORE 1949 TO 1953	TOTAL	FURTHER SECONDARY OPERATIONS	
Thoracoplasty—thoracoplasty	-	4	4	Cavernostomy	1
Thoracoplasty—extrapleural pack	-	5	5	-	
Thoracoplasty—extraperiosteal pack	2	5	7	Revision Resection	1 1
Extrapleural pack—extraperiosteal pack	-	1	1	-	
Thoracoplasty—extrapleural pneumothorax	1	-	1	Resection	1
Thoracoplasty—resection	1	1	2	-	
Thoracoplasty—cavernostomy	1	1	2	Cavernostomy	1
Bilateral resection	3	-	3	-	
TOTALS	8	17	25		5

Results in Bilateral Surgery.—The results varied with the indications, but there were relatively more salvage cases in the bilateral than the unilateral group and hence over-all results were not so good. Patients in the thoracoplasty-plombage group had on the whole a good pre-operative outlook for success. Ten of these 12 patients, or 83 per cent, are well with negative sputum; conversion of sputa was primary in all but one, who finally became negative after revision of the thoracoplasty. The bilateral thoracoplasty group was composed of essentially salvage cases, considered at the time unsafe for resection and found at operation not suitable technically for plomb-

age. Only 1 of these 4 patients (25 per cent) is well with negative sputum; in this case conversion took place only after cavernostomy was performed as a secondary procedure. Of the other 3, one died postoperatively of cardiorespiratory failure, after wax pack removal, and thoracoplasty. Two are alive and well, but with positive sputa at times. They are not respiratory cripples now but probably would be after secondary resection if they survived it.

Bilateral resection was performed on 3 patients; in 2 cases it was for removal of residual foci following the prolonged use of antibiotics. The third was done for persistent positive gastric culture in bilateral minimal apical disease. All three patients are well with negative sputa. The one patient with extrapleural-extraperiosteal pack is well with negative sputum. Of the 2 patients with thoracoplasty resection, one was a good risk with residual foci and is well with negative sputum. The other was a bad risk case with chronic disease and died ten days postoperatively of air embolism of undetermined origin. The 1 patient with thoracoplasty-extrapleural pneumothorax, had borderline respiratory reserve and died postoperatively of cardiorespiratory failure following a secondary resection on the side with the thoracoplasty.

The 2 patients with the combination of thoracoplasty-cavernostomy were in the salvage class and both required further secondary operations. One has had a contralateral cavernostomy for a residual cavity under the thoracoplasty and is still positive, presumably from a tuberculous bronchiectasis. The second has recently had pneumonectomy on the thoracoplasty side and sputum so far is negative.

TABLE VIII. RESULTS OF BILATERAL SURGERY, 1945 TO 1953—25 CASES

	BOTH SIDES DURING 1949 TO 1953	ONE SIDE BEFORE 1949 TO 1953	TOTAL
NUMBER OF CASES	8	17	25
Sputum conversion	6 (78%)	11 (65%)	17 (68%)
Tuberculous Complications			
Postoperative	1 (11%)	0	1 (4%)
Late	0	0	0
Deaths			
Postoperative	1 (11%)	2 (13%)	3 (12%)
Late	0	0	0
Living (July, 1954)	8 (89%)	14 (87%)	22 (88%)
Well and sputum negative	7 (88%)	10 (71%)	17 (77%)
Salvable	1 (12%)	3 (21%)	4 (18%)
Hopelessly ill	0	1 (8%)	1 (5%)
Inadequate follow-up	0	0	0

Table VIII summarizes the results in the 25 patients with bilateral surgery. In 17 of them (68 per cent), final sputum conversion took place. Only 1 patient (4 per cent), had a postoperative complication, namely, some transitory cardiac decompensation following cavernostomy. Postoperative deaths totalled 3 (12 per cent). Of the 22 living patients 17, or 77 per cent, are well with negative sputum; 4, or 18 per cent, are salvable; and one, or 5 per cent, is hopelessly ill.

TOTAL SURGICAL RESULTS

Total results of the 219 cases analyzed are presented in Table IX. Two hundred and seven patients, or 94 per cent, are living, and 12, or 5.5 per cent, are dead. Of the deaths, 10 were associated with tuberculosis and 2 died from other causes. Of those living, 176, or 85 per cent, are well with negative sputum; 15, or 7.2 per cent, have positive sputum, or unstable roentgenograms, but are considered salvable; 5, or 2.4 per cent, are hopelessly ill due to active or progressive disease, or lowered respiratory reserve; and 11, or 5.4 per cent, lack adequate data for accurate classification. The success of any treatment program in the broadest sense is based on its rehabilitation rate; in other words, how many patients are made safe to associate with others and are returned to gainful occupation. On this basis the most significant finding in the whole series is that 176 of the 210 patients, or 80 per cent, are successfully rehabilitated.

TABLE IX. TOTAL RESULTS—ALL SURGERY—219 CASES

Living (July, 1954)	207 (94.5%)
Well with sputum negative	176 (85%)
Salvable	15 (7.2%)
Hopelessly ill	5 (2.4%)
Inadequate follow-up	11 (5.4%)
Deaths	12 (5.5%)
Tuberculous	10
Nontuberculous	2
Follow-up Period	
6 months or more	196 (100%)
1 year or more	160 (81.6%)
2 years or more	117 (60%)
3 years or more	83 (42.3%)
4 years or more	47 (24%)
5 years or more	18 (9.1%)

DISCUSSION

The subject matter of this paper has been the surgical treatment of pulmonary tuberculosis in an isolated sanatorium. The self-contained surgical unit operating in an isolated area has been stressed because I believe it has become unique in these days of resection surgery, or at least surgical series done under such conditions are not commonly reported. Also, the value of any surgical series, other than adding numbers to the already extensive literature, is to present any variations from average, and this applies, not only to material, but also to conditions under which the work was done. The problems of an isolated sanatorium doing its own surgery have already been mentioned in the introductory remarks. In discussing the present series, the influence of these problems on methods and results will be pointed out whenever possible.

The five-year period January, 1949, to January, 1954, brought radical changes in surgery at Manitoba Sanatorium. As elsewhere, antibiotic therapy was the chief factor in the swing from collapse therapy to pulmonary resection. The lack of a resident anesthesiologist for the first years of the period

affected our work in several ways. It obliged us to use local anesthesia supplemented by Pentothal sodium drip for all chest wall operations. In my opinion this is the anesthetic of choice for collapse therapy and the absence of postoperative mortality, wound infection, and spread of disease in the present unilateral series can be partly credited to this type of anesthesia.

O'Brien and associates[5] in an excellent presentation of total statistics from five years of surgery point out that such statistics vary with the type of risk accepted for surgery. In their work these authors state they have attempted to extend surgical help to every patient with a reasonable chance to get well. I agree entirely with this concept, but hold that even with agreement on this major premise no two series will turn out alike in composition. In each case the surgeon's personal preference, plus the tools he has at hand, will shape the nature of his work. Due to limited availability of intratracheal anesthesia in the earlier years of our study, resection was confined mainly to thoracoplasty failures. Where others were doing increasing numbers of primary resection, we were still doing thoracoplasty. No doubt some of these patients should have had primary resection and the incidence of thoracoplasty failure was unduly high. Nevertheless, many were bad risk cases; they withstood thoracoplasty under local anesthesia well and later most of them were successfully rehabilitated by secondary resection. With reduction of disease by prolonged antibiotic therapy and the easier availability of resection surgery, we now do thoracoplasty much less often as a preparatory operation, but in our opinion it still constitutes the safest approach to the surgical treatment of gross, badly cavitated disease. In these cases, we still like to reduce the pleural space and adjust the patient to the loss of function of this side by preliminary thoracoplasty before doing resection.

Our present belief is that there is still a place for limited surgical collapse as a definitive procedure, but the indications for its use have been greatly reduced by the success of limited resection. Limited collapse is best applied by extraperiosteal plombage and our choice of packing material is paraffin rather than Lucite, because it presents a more regular surface for compressing the underlying lung. In our hands the conversion rate for extraperiosteal pack is definitely lower than for limited resection. Limited resection is therefore our choice of operation, except where the operative risk is formidable, especially in the matter of pulmonary reserve. Poor risks tolerate extraperiosteal pack better than any other operative procedure, except cavernostomy, though limited resection may leave them with better pulmonary reserve if they can survive the operation. We are therefore still using extraperiosteal pack in a small number of poor risk cases.

All agree that final judgment on the relative merits of various present-day treatments must await the passage of time. It is not only a matter of choosing between operations, but in some patients with residual foci, time may prove that antibiotics alone will bring about cure. At present, we prefer to resect residual foci if considered caseous and over 1 cm. in diameter. A small group of patients not wishing surgery act as controls for future study. The best argument for resection of residual foci is the over-all relapse rate

of tuberculous patients in past years. Though this justifies concern, present-day antibiotic therapy is already giving promise of more permanent cure. Then too, the relapse rate in well-treated minimal lesions was never high, even before the use of antibiotics. In 1951, I[6] reported a series of 103 patients treated for minimal tuberculosis confined to the apex of one lung. These patients had received treatment predominantly with pneumothorax between 1928 and 1944, before the use of antibiotics, and showed a 91 per cent arrest of disease after 5 to 22 years' follow-up and a death rate of under 2 per cent. It is perhaps true that prolonged treatment of any type gives good results in minimal disease and the most valid reason for resection in these cases is to reduce treatment time, and to improve still further an already favorable outlook. In view of these indications, limited resection for minimal lesions, if justified, must have no mortality and be free of serious or permanent complications.

So far, we have managed to meet these conditions in minimal cases and believe certain factors have been important in avoiding complications. All patients should have at least 4 to 6 months' antibiotic treatment before surgery. Positive sputum, when present, should preferably have been converted. We favor wedge rather than segmental resection and follow the technique of putting tongue and groove forceps about the area to be resected, excising the wedge and then applying a continuous interlocking backstitch under the forceps before removing them. Where the lesion is more deeply placed and the application of forceps involves the risk of compromising the vascular and bronchial supply to other areas, a modified segmental resection is done. In this case, the bronchus to the involved area is first dissected out, cut across, and repaired. The artery and the veins may also be dealt with individually. Upon establishing a line of demarcation, forceps are applied about the segment, which is then excised and the cut surface repaired deep to the forceps, as in a wedge resection. In this way, no raw surfaces are left and all air leaks, even alveolar ones are avoided. In addition, we routinely separate all adhesions of the lung to the chest wall and diaphragm. In our opinion avoiding air leak at operation and freeing the lung completely from chest wall and diaphragm are prime factors in obtaining rapid and complete re-expansion. The lung is expanded as much as possible before the patient leaves the operating room and during the first postoperative day both drainage tubes can almost always be removed following complete re-expansion. Rapid re-expansion and obliteration of the pleural space is the best safeguard against the commonly feared postoperative complications of persisting air leaks, bronchopleural fistulas, and empyema. The foregoing technical considerations are, of course, not confined to the surgical management of minimal lesions, but apply to all resections. As regards lung re-expansion, in the larger resections, we seldom find it necessary to do partial thoracoplasty following lobectomy, or in the common multiple resection combination of upper lobe, plus superior segment of lower lobe. On the other hand, pneumonectomy should, in our opinion, always be combined with thoracoplasty, preferably done before the resection.

Maximal return of respiratory function following resection is of great importance and is favored by rapid re-expansion. We are now doing maximal breathing tests on all patients operated upon before discharge, but this was not done in the present series. However, the degree of return to normal function was evaluated on the basis of roentgenographic appearance, including costophrenic angle changes, diaphragmatic elevation, rib retraction, and pleural thickening. Of the 71 living patients, where less than the whole lung was removed, all have complete re-expansion and only 3 required apical thoracoplasty. In 65, or 91 per cent, there was little or no roentgenographic evidence of diaphragmatic change, rib retraction, or pleural thickening. The remaining 6 showed various degrees of diaphragmatic change, or rib retraction; none showed pleural thickening. There are no respiratory cripples.

It is commonly accepted that antibiotic therapy has not only improved the outlook in pulmonary tuberculosis, but has also changed the pathology of the disease. Medlar and his colleagues[7] describe necrotic encapsulated foci after prolonged antibiotic therapy. The rapid healing of endobronchial tuberculosis under antibiotic therapy with resultant narrowing, blockage, and epithelization of bronchial outlets results in so-called "filled" cavities observed by all in resected lung tissue. I have observed many such soft, puttylike encapsulated areas in operative specimens, especially in patients of Indian blood, after prolonged antibiotic treatment. It is difficult to see how collapse would improve the healing of these areas, and the logical treatment seems resection. If collapse is used, possibly the optimum time to apply it is not after prolonged antibiotic therapy, but at the beginning while bronchial drainage is still adequate and cavities, if present, might heal by the preantibiotic process of collapse of their walls followed by obliteration from fibrosis. Unfortunately, permanent collapse by surgical means, if applied early before much clearing of disease, must be more extensive than for residual foci and with greater sacrifice of respiratory function. As regards pneumothorax, its extensive use was dropped by us, as by most others, before long-term antibiotic therapy became common, so worth-while experience with this combination is lacking. One wonders if this reversible procedure induced at the beginning of treatment and protected by antibiotics might not offer far better results than formerly, and without its previous complications. To those of us who made extensive use of pneumothorax during its heyday, it is interesting to speculate on its further use, but few would abandon present-day resection therapy in its favor, and it seems doubtful if it will again find a place in the armamentarium of the phthisiologist.

As resection surgery continues to rehabilitate more and more chronically ill patients, the appeal for surgical aid from those remaining becomes more urgent. Many of these cases are entirely unfit for resection. In them, we have found an increasing use of cavernostomy. We employ this procedure where vital capacity is too low for resection and source of positive sputum is believed limited to specific areas of cavitation. In the present series, cavernostomy was performed 7 times in 5 patients. One patient had bilateral cavernostomy and another had two cavernostomies on the same side. Of the 7 opera-

tions, 3 were done as primary procedures, and 4 were to drain residual cavities after thoracoplasty. Four of the 5 patients are now negative. In all cases, the cavernostomy wound healed completely following plastic closure, which was done on an average of seven months from the original opening of the cavity.

Any appraisal of trends and results of surgery must deal with certain intangible factors. Not least among them is the patient-doctor relationship which becomes unusually close in an isolated sanatorium. For the doctor a thorough knowledge of the patient, born of long association, is an invaluable aid in estimating surgical risk and controlling the postoperative course. Conversely, the patient develops the confidence and wholehearted acceptance of surgery, so important to a satisfactory result, by his prolonged contact with both surgical staff and other patients, who, on the whole, have had successful surgery.

The doctor's problem is not so much to persuade patients to have surgery, as to dissuade the well-nigh hopeless ones from the attitude that in surgery they have nothing to lose and perhaps something to gain. It is difficult to refuse surgery to such patients and more often than not surgical aid is offered them sooner or later. The greatest risk, of course, is the patient with chronic, bilateral disease, and low vital capacity who is resistant to all antibiotics. Technically, the surgeon is often on the horns of a dilemma; doing less than a lobectomy in the interests of conserving lung tissue may mean dissecting through diseased areas thereby courting the development of empyema and tuberculous wound infection. On the other hand, removal of the whole lobe in an attempt to avoid these complications may lead to cardiorespiratory failure. It is our experience, as elsewhere, that serious postoperative complications and surgical deaths come most often from this type of patient rather than from mishaps in favorable risk cases. In the present series, they were most common in cases of multiple resection. Fortunately, a precarious surgical venture is not infrequently crowned with success. In patients where all other measures have failed, we believe surgery should not be denied if it holds any hope of success.

We can probably look forward to the time when the backlog of bad risk cases has largely disappeared. In the meantime, these patients continue to challenge the ingenuity of the surgeon, sometimes spoiling his surgical statistics, but always stimulating his work by the occasional salvage of those cases previously considered to be hopeless.

SUMMARY

Results are presented of surgical treatment of pulmonary tuberculosis at Manitoba Sanatorium in the five-year period, January, 1949, to January, 1954.

Statistics are given in detail and include patients presenting a variety of indications from pure salvage to resection for residual foci in minimal disease.

Altogether 219 patients received major surgical treatment of parenchymal disease and of these 80 per cent were successfully rehabilitated.

The effect on treatment trends and results of doing surgery in a self-contained surgical unit in an isolated area are discussed in detail.

Some observations on current treatment based on experience with the present series are submitted.

REFERENCES

1. Ross, E. L.: The Surgery of the Tuberculous Belongs to the Sanatorium, Am. Rev. Tuberc. **35**: 575, 1937.
2. Meltzer, Herbert: Thoracoplastic Collapse of Active Progressive Tuberculosis, J. THORACIC SURG. **8**: 627, 1939.
3. Meltzer, Herbert: Results of Thoracoplasty, J. THORACIC SURG. **11**: 84, 1941.
4. Meltzer, Herbert: The Bilateral Surgical Collapse of Pulmonary Tuberculosis, J. THORACIC SURG. **11**: 227, 1941.
5. O'Brian, William B., Wilson, Norman J., Armanda, Orlando, and Vindzberg, William V.: Total Surgical Statistics in the Treatment of Pulmonary Tuberculosis, Am. Rev. Tuberc. **68**: 874, 1953.
6. Paine, A. L.: The Treatment of Minimal Pulmonary Tuberculosis Confined to the Apex of One Lung, Am. Rev. Tuberc. **63**: 644, 1951.
7. Ryan, B. J., Medlar, E. M., and Weller, E. S.: Simple Excision in the Treatment of Pulmonary Tuberculosis, J. THORACIC SURG. **23**: 327, 1952.

ANEURYSM FORMATION IN A HOMOLOGOUS AORTIC GRAFT IN A HUMAN*

Report of a Case

Owen Gwathmey, M.D., and Charles Waters Thompson, M.D.
Washington, D. C.

HOMOLOGOUS aortic grafts have been used in the human since 1946[1] to replace segments of the aorta for various pathologic conditions. To our knowledge, there has been no report of the development of an aneurysm in a homologous aortic graft in man. Grindley,[2] Sewell,[3] Parsons, Gerbode, and Cox,[4] Johnson and Kirby[5] and others have reported formation of aneurysms in replaced autogenous and homologous aortic and venous grafts in the experimental animal. Grindley[2] described the occurrence of an aneurysm in an aortic homograft implanted in a dog for two years. Sewell[3] stated that aortic homografts sterilized with ethylene oxide frequently produce aneurysmal dilatation and rupture and believed this was due to destruction of the elastic tissue from the ethylene oxide treatment.

Coleman, Deterling and Parshley,[6] Kanar and associates,[7] McCune and Blades,[8] Sewell,[3] Hufnagel,[9] Hufnagel and Eastcott,[10] Shumacker and King,[11] Gross,[1] Swan,[12] DeBakey and associates[13] and others have described the fate of homologous grafts of the aorta. There is usually a marked thinning of the graft wall, loss of cellular elements, disruption of the elastic framework, and mild to marked calcific deposits. Arterial homografts do not show persistence of their cellular elements, but serve as the scaffolding for the ingrowth of connective tissue from the host to provide a conduit for arterial blood. The endothelium covering the intimal surface is thought to be derived from the fibroblasts and possibly endothelium of the adjacent host aorta. The blood is supplied from the surrounding tissues.

CASE REPORT

A 60-year-old white woman was admitted to the George Washington University Hospital on Jan. 11, 1954, complaining of upper abdominal and flank pain on the left, of one year's duration. This pain was dull in nature but made worse by exertion. It persisted and became much more severe five weeks before admission, requiring opiates for relief. At that time, she observed swelling and tenderness along the left costal margin. The patient gave a history of indigestion of two years' duration, relieved by sodium bicarbonate. A 17 pound weight loss was noted during this time. She had had a hysterectomy twelve years previously and a known hypertension, with systolic pressures of 220 mm. of mercury, for years. She was referred to us because of accentuation of her symptoms and evidence of a pulsating mass in the abdomen.

From the Departments of Surgery and Medicine, The George Washington University School of Medicine, Washington, D. C.

Received for publication Jan. 28, 1955.

*This investigation was supported in part by a research grant (H-142) from the National Institutes of Health, Public Health Service.

On physical examination, the patient was a well-developed and fairly well-nourished 60-year-old woman, who appeared chronically ill but in no distress. Her pulse was 84; blood pressure 170/110 mm. of mercury and temperature 37° C. There was Grade II spasm of the arterioles on examination of the fundi. The heart was not enlarged and no murmurs were heard. A well-healed, lower midline abdominal scar was noted. Deep palpation of the abdomen elicited pain in the left upper quadrant, left mid-abdomen, and left flank. There was no paresthesia but hyperesthesia was noted over the area of tenderness. A pulsating elongated mass, about 4 cm. in width, was felt in the region of the aorta, which could be followed from the sacrum to beneath the xiphoid.

The laboratory reported hemoglobin 14.4 Gm. per 100 c.c., hematocrit 47 per cent, leukocyte count 10,900 with 64 per cent seqmented neutrophils, 32 per cent lymphocytes, and 4 per cent monocytes. The erythrocyte sedimentation rate (Wintrobe) was 16 mm. after one hour. The Kahn and cardiolipin (V.D.R.L.) tests for syphilis were negative. The urine was yellow with a specific gravity of 1.029 and an acid reaction with no albumin or sugar. There were 1 to 3 leukocytes per high-power field. Serum nonprotein nitrogen was 25 mg. per cent and the van den Bergh test was negative.

There was questionable left ventricular hypertrophy on the electrocardiogram.

Roentgenographic studies of the chest proved the heart shadows normal, the lung fields clear, and an aneurysmal dilatation of the descending thoracic arota. To a lesser degree, there was dilatation of the abdominal aorta. There was considerable calcification of the ascending arch and abdominal aorta, but the dilated portion of the descending aorta was not outlined with calcium. The vertebrae were not eroded. On angiocardiograms, made by Doctor A. D. Kistin, a fusiform dilatation of the descending thoracic aorta was seen, with a thick wall extending from the sixth thoracic vertebra to the diaphragm (Fig. 1). The abdominal aorta appeared tortuous and somewhat wider than normal with no localized aneurysmal formation.

On Jan. 20, 1954, under Pentothal sodium and ether anesthesia induction, tracheal intubation was carried out. The anesthesia was maintained with nitrous oxide, oxygen, and ether. A thoracodorsal incision was made and the eighth rib removed subperiosteally. The pleural cavity was opened and the lung collapsed. The aorta was tortuous and enlarged in its course from just below the arch to the diaphragm. Approximately 7 cm. below the subclavian artery the aorta ballooned and, for a length of 5 cm., was twice the size of the normal-appearing vessel. From this point, it increased to about three times the normal size for 10 cm. where it abruptly narrowed and made an acute angle with the distal aorta. In the wall of the aorta numerous calcified plaques were palpable. There were several 0.5 to 1 cm. dimples in the wall which appeared thinner and pulsated vigorously.

The mediastinal pleura was incised. The aorta was mobilized from the diaphragm to approximately 5 cm. below the arch, with individual ligation of all intercostal and esophageal vessels. At this point, the tortuosity was much more evident and the ballooning of the small dimples was more pronounced.

Because of the preoperative suspicion of an abdominal aneurysm, the diaphragm was opened. On palpation, the abdominal aorta was slightly tortuous and dilated, but without evidence of aneurysm formation. The diaphragm was closed with interrupted silk sutures. The sixth and seventh ribs were cut posterior to their angles for wider exposure. A freeze-dried aortic graft untreated with ethylene oxide, obtained from The Walter Reed Army Medical Center, was reconstituted. All its small branches were doubly ligated with 4–0 silk by another team. A Potts' clamp was applied proximally and distally to the aneurysm and the aneurysm excised. It measured 17 cm. in length. The proximal aorta contained several yellowish plaques in its intima which were dissected free. The graft was anastomosed to the aorta using two lateral stay sutures of 4-0 silk, and, also, running posterior and anterior sutures of the same material. The aorta was clamped for forty minutes. The blood pressure prior to aortic occlusion was 160/100. After occlusion it rose promptly to 240/100. A phlebotomy of 750 c.c. was performed and Pendiomide (22 mg.) was administered for its

hypotensive effect. The blood pressure fell to 120/80. For four minutes after the clamps were released, there was no blood pressure obtainable. The blood withdrawn by phlebotomy was rapidly reinfused and within fifteen minutes the blood pressure was 100/60.

The graft assumed an inverted U position which made its distal end kink just above the line of anastomosis. Because of the kink, it was necessary to resect a portion of the graft. Once again the distal and proximal host aorta was cross-clamped and a 4 cm. segment of aortic graft, directly in the center of the graft, was removed. The graft was reanastomosed. The time of the second occlusion was twenty minutes.

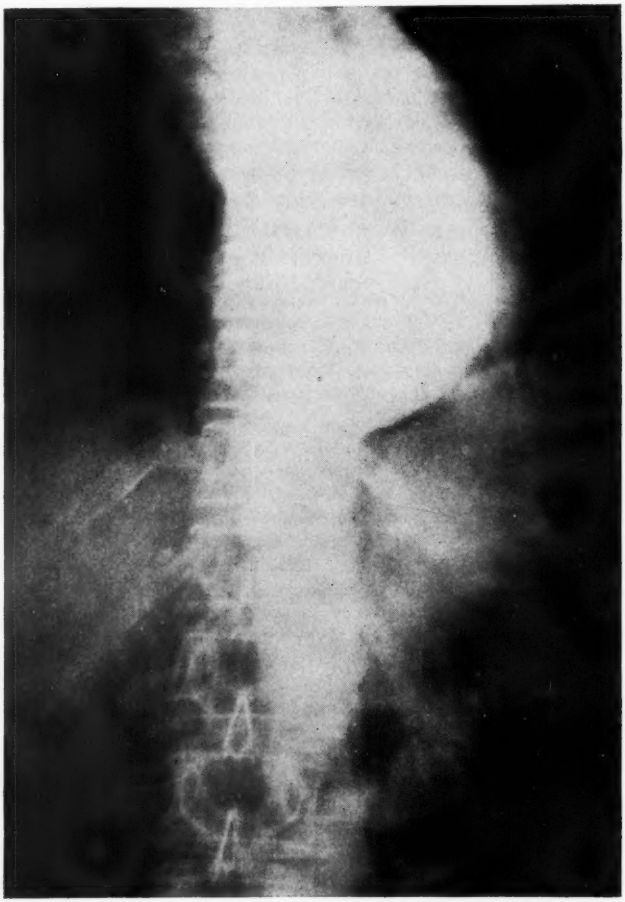


Fig. 1.—Original aneurysm as seen on an angiocardiogram.

The graft lay nicely in the bed with no tortuosity or kink, and hemostasis was easily controlled with several interrupted silk sutures.

The blood pressure rose to 160/90 following the second cross-clamping of the aorta and fell to 90/0 after the clamps were released. It soon rose to 120/80 and remained at that level throughout the completion of the operation.

It was impossible to close the mediastinal pleura. The thoracotomy incision was closed, leaving an intercostal catheter for water-seal drainage.

The patient tolerated the procedure well and was returned to her room in good condition with palpable dorsalis pedis pulsations.

Grossly, the host specimen consisted of a segment of aorta measuring 12.5 cm. in length and averaging 4 cm. in width. At one end there was a 1 to 2 cm. saccular aneurysmal dilatation. The intima was markedly thickened and contained yellowish-white atheromas with areas of calcification.

A second specimen consisted of an 8 mm. segment of aorta measuring 1.8 cm. in diameter, labeled "Segment of homologous aorta."

On microscopic examination of the host aorta, there was profound intimal thickening and proliferation with many cholesterol clefts and mononuclear macrophages containing hemosiderin. Focal areas of basophilic stippling marked the sites of calcification. The media was thinned beneath the atheromatous plaques, but showed no evidence of mucoid degeneration. The adventitia was the site of recent hemorrhage (operative), but otherwise showed no abnormalities. The vasa vasora and vena vasora were normal in appearance.

Microscopically, the intima of the segment of homologous graft was not thickened. The media was normal in appearance. There were no breaks in the elastica and no "palisading" of nuclei was seen. Very little adventitia was seen in the portion of transplant submitted for study (Fig. 2, *A*).

Immediately after returning to the ward, the patient's blood pressure rose to 160/110. Six hours later it fell to 90/70 and remained so for six hours. It then rose to 200/110 and varied in this region throughout the hospital stay.

In the first twenty-four hours the urinary output was 360 c.c. and the nonprotein nitrogen was 47 mg. per cent. The second postoperative day the urinary output was 1,100 c.c. and the nonprotein nitrogen was 43 mg. per cent. The third postoperative day diuresis to 2,200 c.c. occurred and the nonprotein nitrogen was 62 mg. per cent. On the fourth postoperative day the nonprotein nitrogen was 35 mg. per cent, serum potassium 4.8 mg. per liter, serum sodium 151 meq. per liter. The patient continued to improve and was discharged on the twelfth postoperative day, her only complaint being some vague left upper abdominal pain. The blood pressure was 180/120 and the peripheral pulsations of all vessels were satisfactory.

Comment.—The aorta was clamped for a period of forty minutes for the original anastomosis and again for twenty minutes in order to remove a segment of the graft because of kinking and partial obstruction of the blood flow. This possibly accounts for the transient oliguria and retention of the nitrogenous products. Studies for hepatic damage and blood incompatibility were negative.

Hepatic and renal injuries are not noted in resections of coarctations with primary anastomosis or replacement by a homograft because of the tremendous collateral circulation.[14] On the contrary, in aneurysmal disease there may be serious complications because of the lack of the development of adequate collateral circulation and because of thrombosis of the intercostal vessels found in arteriosclerotic diseases with aneurysms.[15] DeBakey, Cooley, and Creech[16] stated that the closer the aorta is cross-clamped to the arch, the more likelihood of spinal cord injury. This would seem true, also, for the liver and kidneys if the aorta is clamped above their blood supply. If, however, the occlusion is below the renal vessel, there is usually no damage to vital organs.

Toleration of occlusion of the aorta appears to vary greatly in different individuals. Lam and Aaron[17] cross-clamped the aorta for twenty-five minutes and again for fifteen minutes and noted a transient cord damage in a resection of an aneurysm of the thoracic aorta. DeBakey[14] has occluded the thoracic aorta for forty-five minutes and Brock and Graham[18] for eighty minutes with no cord or renal damage. Beattie and co-workers[19] and Lam and Aaron[17] have also demonstrated that the time required to produce cord damage by aortic occlusion in the experimental animal is quite variable.

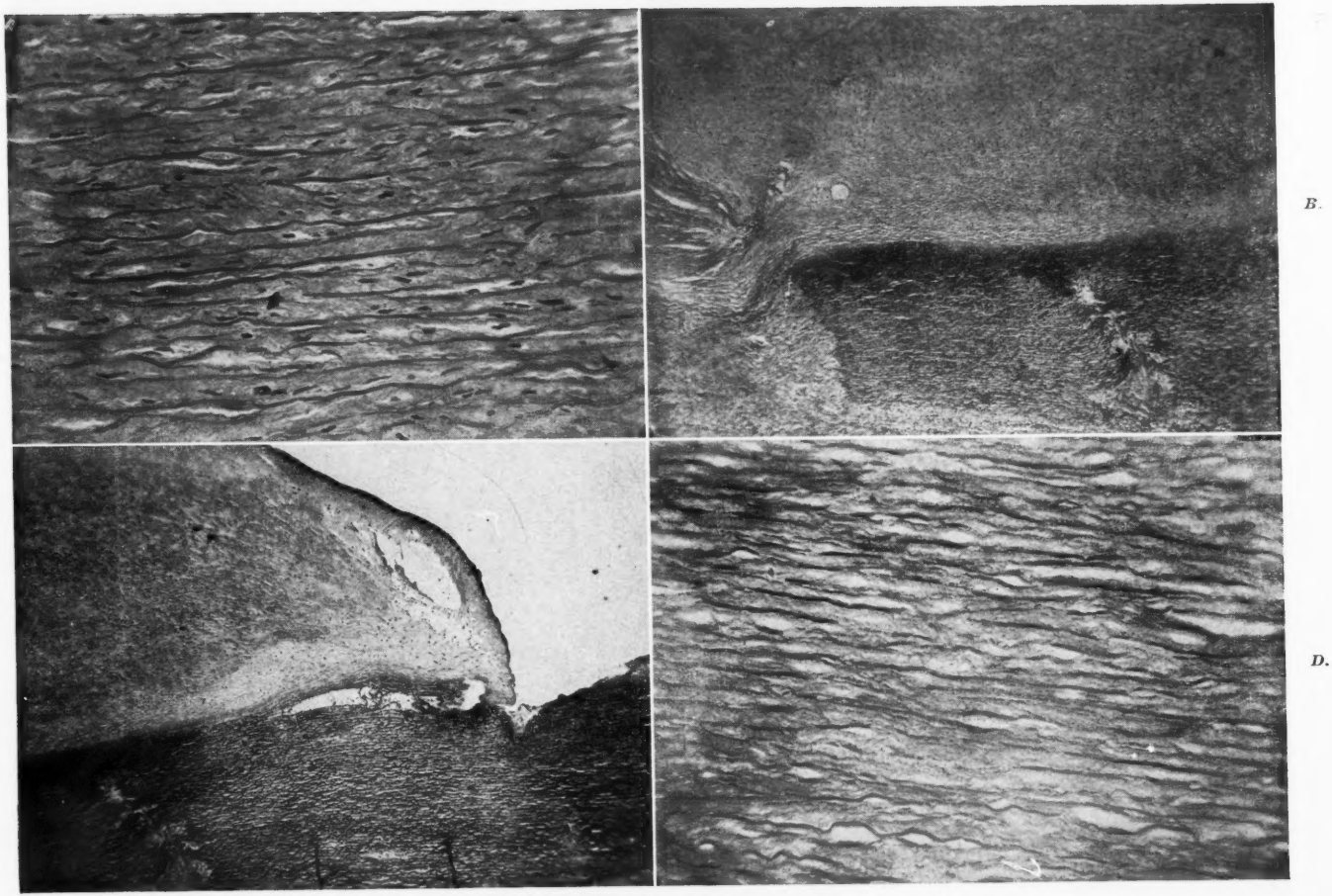


Fig. 2.—*A*, Section of the original freeze-dried homologous aortic graft, showing the media and nuclei to be normal in appearance. *B*, Section of aortic graft and host aorta one year after transplant, showing the line of demarcation between the graft and the patient's aorta and an atheromatous plaque above it. *C*, Section of aortic graft and host aorta, showing the atheromatous plaque as it extended over the graft from the host aorta. *D*, Section of the aortic graft one year after transplanting. No nuclei are seen.

Second Admission.—On May 20, 1954, the patient was readmitted to the George Washington University Hospital with a four-week history of intermittent rash of the lower extremities, malaise, anorexia, chills, sweats, and fever. There was arthralgia of a migratory nature and redness and heat in the affected joints. Two weeks prior to this admission, she was hospitalized in her home town for six days. There, a leukocytosis of 25,000 was noted, which rose and fell with intermittent fever. She had a recurrence of pain in the left flank and chest, reminiscent of the pain prior to removal of the aneurysm in January, 1954. On physical examination, the blood pressure was 180/105 in the right arm, pulse 100, respirations 18, and rectal temperature 39° C. She appeared chronically ill and there was evidence of weight loss. Hepatosplenomegaly was noted. All pulses in the feet were present bilaterally. There were no nodes palpable. The heart sounds were normal. The radiologist reported "questionable bulge in the region of the operative site."

The white blood count varied from 8,000 to 10,200, with a normal differential except for elevated eosinophils from 8 to 10. The hemoglobin was 11.8 Gm. and the erythrocyte sedimentation rate was 27 mm. (Wintrobe) after one hour. The urine remained negative and concentrated to 1.014. A bromsulfalein liver function test of 25 per cent retention was reported and substantiated. Serum bilirubin was 0 mg. per cent direct and 0.3 mg. per

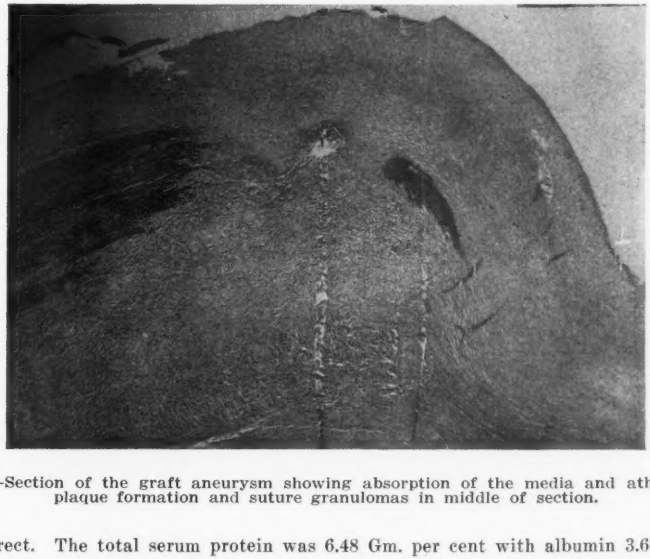


Fig. 2*E*.—Section of the graft aneurysm showing absorption of the media and atheromatous plaque formation and suture granulomas in middle of section.

cent indirect. The total serum protein was 6.48 Gm. per cent with albumin 3.65 Gm. per cent and globulin 2.83 Gm. per cent. The thymol turbidity was 5 units and a cephalin flocculation was reported as 1 plus in 24 hours. The Kunkel globulin was 11 units. The sternal marrow biopsy was "compatible with infection but otherwise normal." Culture of the marrow, repeated blood cultures, and a femoral artery culture remained sterile. Proteus and *Escherichia coli* were recovered from a urine culture. Multiple agglutinations were negative. No blood, ova, or parasites were seen in 3 stool specimens. The blood urea nitrogen was 13 mg. per cent.

Even on large doses of salicylates the fever persisted. In spite of negative venous and arterial cultures, the diagnosis of endarteritis at the graft site seemed tenable. Massive doses of penicillin were instituted, as in the treatment of endocarditis, with a prompt subsidence of temperature and a return of well-being. She was discharged and was to continue to take penicillin at home for another three weeks.

Fig. 2.—*A*, Section of the original freeze-dried homologous aortic graft at the line of demarcation between the graft and the patient's aorta showing the suture line and host aorta. Section of aortic graft and host aorta one year after transplant, showing the line of demarcation between the graft and host aorta, shewing the atheromatous plaque as it extended over the graft and the host aorta. Section of the aortic graft one year after transplanting. No nuclei are seen.

The diagnoses at discharge on June 5, 1954, were endarteritis at graft site, hepatitis, and hypertension. The cause of the hepatitis remained obscure.

Comment.—In retrospect, the aneurysm in the graft was present at this admission, evidenced by a return of her preoperative pain and the x-ray appearance of the chest.

Lower extremity petechiae, migratory arthralgia, chills, sweats, malaise, and anorexia promptly subsided with the institution of penicillin therapy, making a diagnosis of endarteritis at the graft site reasonable, in spite of negative cultures.

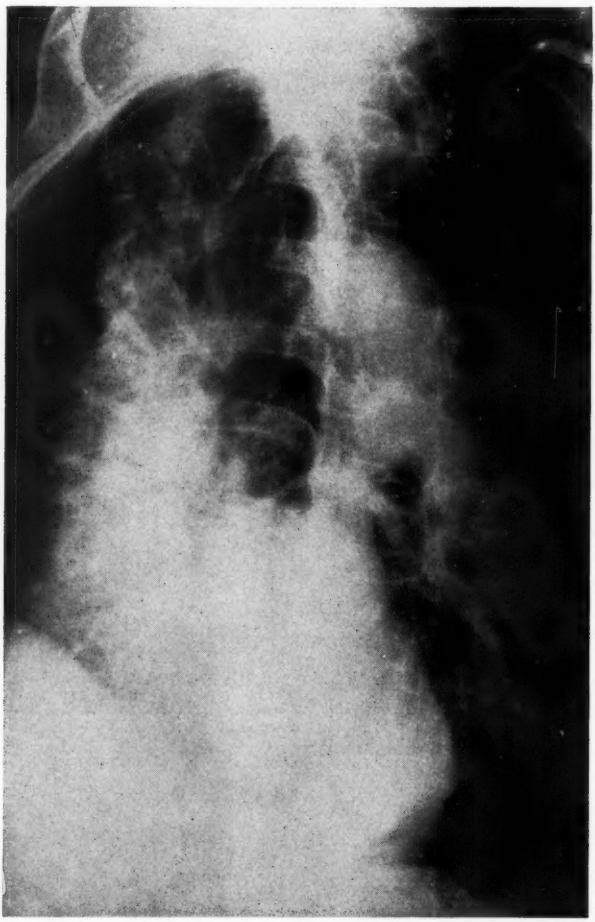


Fig. 3.—Anterior oblique film showing the kink and aneurysm in the graft one year after transplant as seen on an angiocardiogram.

The etiology of the hepatitis remains obscure. Hepatic damage could have occurred from aortic occlusion at the time of surgery, from blood transfusions, or as a response to the endarteritis.

Interval History.—During the summer of 1954, she gained strength and vigor, but noted intermittent pain in the left flank and chest, particularly when her blood pressure rose. Liver

function tests returned to normal, but there was evidence of a considerable difference in the blood pressure in either arm, the right being higher than the left. Serpasil in large doses did not affect the hypertension. She was taught to take her blood pressure at home in preparation for administration of ganglionic blocking agents.

Because of the great discrepancy in the blood pressure in the two arms, and because of a steady rise in her hypertension, she was hospitalized again in early December, 1954, with the suspicion of another aneurysm in the arch. The intermittent pain had become constant.

Under the fluoroscope, a pulsating mass was seen in the graft site, but no other aneurysm was noted. Sodium Amytal sedation lowered the 240/130 pressure in the right arm to 130/80. Renal and hepatic function were excellent at that time. The patient was discharged before starting ganglionic block with drugs because she desired to attend to some personal affairs. However, an acute exacerbation of her symptoms required readmission to the hospital in a few days.

Final Admission.—On this admission, the patient appeared quite apprehensive and in acute distress. She was unable to lie on her left side. The pulse was 82 and regular. Blood pressure in the right arm was 225/110 and 160/100 in the left arm. In the right leg, the pressure was 180 systolic; the diastolic pressure was not obtained. There was no change in the eyegrounds. Moist râles were heard posteriorly in both lower lung fields and acute tenderness was elicited in the left midquadrant of the abdomen and left flank. The widened abdominal aorta was again palpated with strong pulsations. The pulsations of the vessels of the lower extremities were decreased but present.

The laboratory findings were hemoglobin 14.8 Gm., hematocrit 50 per cent, and leukocytes 8,250 with 61 segmented neutrophils and 34 monocytes. The blood urea nitrogen was 19 mg. per cent. The urine was yellow and acid in reaction with a specific gravity of 1.011. Other urine studies were negative.

On roentgenographic, fluoroscopic, and angiocardiographic studies, sharp angulation at the lower part of the descending thoracic aorta was noted, with a prominent rounded bulge at this site (Fig. 3).

On Jan. 3, 1955, a right thoracoabdominal incision was made through the old scar. The lung was closely adherent to the bulging graft. The aorta was freed proximally and distally and encircled with umbilical tapes. The lung was dissected from the graft. A considerable amount of oozing was encountered. The graft had again formed an S-shaped tube with the aorta and a localized aneurysmal dilatation was noted at the anastomotic site, which was 4 cm. in width and pulsated against the eighth, ninth, and tenth ribs (Fig. 4). It is important to record that the original aortic graft was not treated with ethylene oxide.

The entire graft and aneurysm were freed from the surrounding tissues from the celiac axis to 2 cm. below the subclavian artery. Intrathoracic hypothermia[20] was established allowing the temperature to fall to 31° C. to aid in preventing damage to the vital structures. The fifth rib was resected and the pleura divided for more adequate exposure.

The length of graft required was measured and a Vinyon N tube* the size of the aorta was cut to that measurement, allowing an overlap of 2 cm. to be folded upon itself at each end. The aorta was occluded proximally and distally. The graft and adjacent aorta, 2 cm. on each end, were excised. The Vinyon N graft was then anastomosed using two lateral stay sutures of 4-0 silk, and running posterior and anterior sutures of the same material. The clamps were released with slight bleeding from a needle hole at the distal anastomosis, which promptly ceased (Fig. 5). The aorta was cross-clamped for thirty-three minutes.

The blood pressure at the beginning of the operation was 160/100 and 110/80 prior to occlusion of the aorta. It promptly rose to 220/100 and remained stable until the clamps were released, at which time it fell to 110/60 and did not deviate throughout the

*The authors express their appreciation to Drs. William Sewell and Robert Koth of the Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland, for supplying the Vinyon N graft and technical advice in its use.

Fig. 4.—Graft in the thoracic aorta with kink and aneurysm formation.

Fig. 5.—Vinyon N tube replacement in descending thoracic aorta.

completion of the procedure. The diaphragm and chest wall were closed. A water-seal drain was placed in the pleura. Blood totaling 2,300 c.c. was given intravenously. The patient's condition was satisfactory throughout the procedure. All peripheral pulses were easily palpated and of good quality at the completion of the operation.

Grossly, the specimen consisted of a segment of aorta measuring 14 cm. in length with an average diameter of 3.2 cm. in its unopened state. There were three suture lines. The middle anastomosis was 8 cm. from the proximal end and was intimately associated with a saccular aneurysmal dilatation or evagination measuring approximately 3.0 cm. The proximal line of anastomosis was located 3 cm. from the proximal end of the specimen. There was marked atherosclerosis of the patient's own aorta evidenced by grayish-white to yellow plaques, and at two points these plaques extended on the proximal portion of the graft for a distance of 0.5 cm. They could be peeled off the underlying graft which was still smooth and grayish-white. There were two small yellowish plaques in the graft proper and these were found at the middle suture line at the stoma of the aneurysmal sac. The larger of the two measured 0.3 cm.

At the distal suture line, which was 2 cm. from the lower end of the specimen, an abrupt change from the smooth graft surface to the patient's own sclerotic aorta was again noted. The degree of sclerosis here was equivalent to that found at the proximal end. Several plaques extended on the distal end of the graft and these again could easily be peeled off. The intimal surface of the aneurysm was somewhat more wrinkled and thicker than the rest of the graft.

Seen in microscopic sections from the proximal end of the patient's own aorta was marked atherosclerosis evidenced by intimal thickening and sclerosis. There was infiltration by fibroblasts. There were plaques under which the media was thinned, but intact. Suture granulomas were seen with a foreign body tuberculoid reaction. Obliterative endarteritis and focal perivascular accumulations of lymphocytes and mononuclear macrophages were also noted. The line of demarcation between the graft and the patient's own aorta was striking (Fig. 2, *B*). There was no thickening of the intima of the graft. The continuation of the intimal plaque from the patient's vessel to the surface of the graft was easily seen (Fig. 2, *C*). The media of the graft was relatively acellular except in one area close to the proximal suture line where a flame-shaped scar extended inward from the adventitia (Figs. 2, *B*, and *C*). Beyond this area, the media was almost devoid of nuclei (Fig. 2, *D*). The adventitia was widened, markedly sclerotic, and there was recent hemorrhage (operative) in the periadventitial fibro-fatty tissue.

TABLE I. LABORATORY WORK

POSTOPERATIVE DAY	URINARY OUTPUT	HEMATOCRIT PER CENT	BLOOD UREA NITROGEN MGS. PER CENT	Na MEQ. PER CENT	K. MEQ. PER CENT	Cl MEQ. PER CENT	CO_2 MEQ. PER CENT
1	350 c.c.	43					
2	360 c.c.	35	54	129	5.2	94.0	17
3	2,700 c.c.	28	65	136	5.0	92.0	23
4	3,400 c.c.	33	75	134	3.6	93.7	18
5	3,500 c.c.		60	144	4.0	95.0	21
6	3,175 c.c.	41	37			96.4	20
7	2,320 c.c.	42	36	144	3.9	95.3	
10	2,000 c.c.	39	28	135	3.6	107.0	20

The only areas of intimal plaque formation in the graft proper, together with focal areas of almost complete absorption of the media, were seen in sections from the middle suture line and aneurysm stoma (Fig. 2, *E*). In these areas, the thickened intima was almost in opposition to a widened sclerotic adventitia. The intimal plaques in this area were frequently but not always related to suture. The greatest degree of intimal thickening was noted at the outpouching of the sac.

The distal anastomosis was similar to the proximal suture line and the marked atherosclerosis of the patient's own aorta was noted again.

Most of the graft segment showed almost no visible nuclei in the media, with two exceptions—one close to the area of the proximal anastomosis where the flame-shaped scar was noted and the other in the vicinity of the middle suture line. This loss of nuclei was most strikingly seen by comparing the section of the transplant taken just prior to the initial placement of the graft with the resected specimen from the second procedure (Figs. 2, *A* and *D*).

Soon after the operation the patient developed a sinus tachycardia to 140 beats per minute, and the blood pressure rose to 156/90. She was awake and oriented. The electrocardiogram confirmed the sinus tachycardia and was otherwise normal. It remained so throughout her hospital stay. At the end of the first twenty-four hours, the urinary output was 350 c.c. This urine concentrated to 1.014 and there were many red cells, hyaline and granular casts seen in the noncentrifuged specimen (Table I). The second postoperative day the patient voided only 75 c.c. in sixteen hours. Fluids were limited to a total of 1 L., which consisted of 750 c.c. of a mixture of physiological sodium chloride and ⅙ molar lactate to provide an excess of sodium. The hematocrit had fallen and 250 c.c. of whole blood followed this mixture intravenously. Diuresis began on the third postoperative day and liquids by mouth were started. Following that, the patient was given electrolytic solutions and blood as indicated by the daily laboratory findings (Table I). Oral feedings were given as tolerated, in spite of which she continued to have a mild acidosis and mild hypochloremia. This was treated with potassium chloride orally.

Nausea and some vomiting were a problem during the postoperative course and were attributed to a known intolerance to narcotics which averaged only 2 to 3 hypodermics per day.

At the time of discharge the patient was free of pain and complained only of soreness from the incision.

COMMENT

There were several factors contributing to the aneurysm formation in the graft. There probably was a persistent kink in the graft unrecognized at the time of the first procedure, although it was believed that defect had been corrected. Hypertension increased the force of the jet which bombarded the graft already weakened by the endarteritis noted on her second hospital admission.

It is interesting that the calcific deposits were found only at the anastomotic sites, the graft being singularly free of atheroma or calcium deposits except at suture lines.

McCune and Blades[8] have demonstrated aneurysm formation in grafts of dogs' aortas where kinking occurred. Infection has long been an etiological factor in aneurysms.

CONCLUSION

The recognition and removal of an aneurysm which occurred in a homologous aortic graft are reported. Possible factors in the occurrence of the aneurysm are noted.

REFERENCES

1. Gross, R. E.: Treatment of Certain Aortic Coarctations by Homologous Grafts, Am. Surgeon **134**: 753, 1951.
2. Grindley, J.: Reported by Coleman, C. C., Jr., Deterling, R. A., and Parshley, M. S.[6]
3. Sewell, W. H.: Personal communication.

4. Parsons, H. G., Gerbode, Frank, and Cox, A. J.: Studies in Aortic Homografts. Do Homografts Survive? Angiology **3**: 306, 1952.
5. Johnson, Julian, Kirby, C. K., and Hardy, J. D.: Aneurysm Formation in Experimental Vein Grafts in the Thoracic Aorta, Surgery **33**: 207, 1953.
6. Coleman, C. C., Jr., Deterling, R. A., and Parshley, M. S.: Some Long Term Observations on Aortic Homografts, Surgery **37**: 64, 1955.
7. Kanar, E. A., Nyhus, L. M., Schmitz, E. J., Savage, L. R., Moore, H. G., and Harkins, H. N.: Experimental Vascular Grafts II, Am. Surgeon **19**: 915, 1953.
8. McCune, W. S., and Blades, B.: Viability of Long Blood Vessel Grafts, Am. Surgeon **134**: 769, 1951.
9. Hufnagel, C. A.: Personal communication.
10. Hufnagel, C. A., and Eastcott, H. G.: Homologous Arterial Grafts, Bull. Georgetown Univ. M. Center **4**: 119, 1951.
11. Shumacker, H. B., Jr., and King, Harold: The Use of Pliable Plastic Tubes as Aortic Substitutes in Man, Surg., Gynec. & Obst. **99**: 287, 1954.
12. Swan, H., Fechan, J. J., Florio, L., and Johnson, R. T.: Arterial Homografts IV. Preservation of Tissue Culture Viability of Canine Aortic Segments After Freezing at Low Temperatures, Surgery **31**: 807, 1952.
13. DeBakey, M. E., Creech, O., Jr., Cooley, D. A., and Halpert, B.: Structural Changes in Human Aortic Homografts: Study of Ten Cases, A. M. A. Arch. Surg. **69**: 472, 1954.
14. DeBakey, M. E., and Cooley, D. A.: Successful Resection of Aneurysm of Thoracic Aorta and Replacement by Graft, J. A. M. A. **152**: 673, 1953.
15. Moore, S. W.: Resection of the Abdominal Aorta With Defect Replaced by Homologous Graft, Surg., Gynec. & Obst. **99**: 745, 1954.
16. DeBakey, M. E., Cooley, D. A., and Creech, Oscar, Jr.: Treatment of Aneurysm and Occlusive Disease of the Aorta by Resection, J. A. M. A. **157**: 203, 1955.
17. Lam, C. R., and Aaron, H. H.: Resection of the Descending Thoracic Aorta for Aneurysm, Am. Surgeon **134**: 743, 1951.
18. Brock, R. C., and Graham, A. P.: Resection of Combined Aneurysm and Coarction of the Aorta With Insertion of a Homograft, Guy's Hosp. Rep. **101**: 207, 1952.
19. Beattie, E. J., Jr., Adovasio, W., Keshishian, J. M., and Blades, B.: Refrigeration in Experimental Surgery of the Aorta, Surg., Gynec. & Obst. **96**: 711, 1953.
20. Blades, B., and Pierpont, H. C.: A Simple Method for Inducing Hypothermia, Ann. Surg. **140**: 557, 1954.

ALVEOLAR-CELL CARCINOMA OF THE LUNG (PULMONARY ADENOMATOSIS)

A Study of 155 Cases, 10 Reported for the First Time

H. Ryerson Decker, M.D.
Pittsburgh, Pa.

ALVEOLAR-CELL carcinoma of the lung or pulmonary adenomatosis is a primary malignant tumor which is increasingly recognized and reported as time goes on. There has been some confusion in nomenclature; some difference of opinion as to cell origin; considerable difficulty in reaching a diagnosis ante mortem, and substantial failure to treat the patient with the affliction successfully. While some observers have come to believe that alveolar-cell carcinoma is a late stage of pulmonary adenomatosis when metastases may have developed, it is certain that they are the same tumor. Alveolar-cell carcinoma is the preferable designation. The nomenclature applied to this disease variously has been papillary gelatinous adenocarcinoma, primary alveolar-cell tumor, pulmonary adenomatosis, muco-cell papillary adenocarcinoma, diffuse epithelial hyperplasia, diffuse primary alveolar epithelial carcinoma, malignant adenoma, cystic papillary lung tumor, muco-epithelial hyperplasia, carcinomatoides alveologenic multicentric.

The earliest records of the tumor are by Malassez in 1876 and Musser in 1903. Since then desultory reports have been published, which have become more numerous in the last fifteen years. Even so, I have been able to find only 145 proved case reports to which are now added 10 that have come under my personal care or observation. It is very likely that many cases have escaped recognition because of the difficulty of diagnosis. Clagett found 7 cases in 275 lung resections. Ikeda found 8 in 206 proved cases of carcinoma of the lung. Adler reported 20 in 374 primary malignant growths of the lung. Paul believes that 20 per cent of all pulmonary malignancies are composed of alveolar carcinomas.

The etiology of the tumor is not established. Undoubtedly it develops as a response to a single or many factors, and to certain nonspecific irritants as is true of cancer in general. The most intriguing idea is that of causation by a virus or by peculiar ultramicroscopic bacteria, because of its morphological resemblance to epidemic zaagsiekte of sheep. This disease was the subject of a thorough study and report made by the African Expedition of the Rockefeller Institute for Medical Research. They found that the zaagsiekte (sometimes spelled jagziekte) is a specific catarrhal pneumonia in sheep peculiar to South Africa. Initial symptoms are noticeable when sheep are driven for long distances, hence the designation "drive sickness." The pneumonia begins with engorgement of the capillaries. It is followed by accumulation of macrophages

Received for publication Jan. 31, 1955.

and lymphocytes with many mucous plugs passing into the alveolar lumina. There is definite thickening, several millimeters in diameter in localized areas of interalveolar tissue. Then epithelial papillary proliferation develops in the alveoli. It seldom gives rise to metastasis even to adjacent lymph glands, probably because death occurs before metastases have a chance to develop. Primary infiltration of interalveolar tissue continues, and may lead to fibrosis and consolidation; or leukocytes may accumulate in large numbers, penetrate into the alveoli, and form areas of acute pneumonia. There are many stages of reaction in one and the same lung. The prevailing view that the zaagsiekte is due to a specific virus and is directly contagious is in all likelihood correct, in spite of the failure to transplant the disease by direct inoculation or by inhalation of diseased tissue. Thus, while zaagsiekte may be due to a single and specific virus, the pathological complex on the whole is such as might be caused by a variety of predisposing and exciting factors over a considerable period of time. Perhaps, in the naturally occurring disease, interalveolar thickening is such a factor. In the search for microorganisms, no nematodes nor parasites (for example, malarial organisms) were found. Several kinds of bacteria were present, but never in proliferating epithelium as is true of most hyperplasias and tumors. The adenomatous condition present is merely a kind of epiphenomenon. Very likely the pulmonary alveolar epithelium of sheep is peculiarly unstable, and is unusually susceptible to growth stimuli or to influences tending to invalidate normal inhibitory mechanisms. Epithelial proliferatoin, though supplementary, contributes to the death of the animal by diminution of respiratory area, and a lessening of their vitality, thus rendering the sheep more susceptible to bacterial action.

In the human being, hyperplasia and metaplasia in the pulmonary alveoli can be produced by various stimuli. They are observed in:

1. Bacterial and viral: (a) pneumonitis, (b) empyema, (c) pleurisy, including old pleuritic adhesions, (d) chronic granuloma, for example, syphilis and tuberculosis, and (e) lung abscess and gangrene.

2. Nonbacterial pneumonitis: (a) lipoid, (b) chemical, and (c) aspiration.

3. Vascular disturbance which produces chronic anoxia as in an old mitral and aortic valvular disease which develops chronic passive congestion, infarcts, atelectasis, and fibrosis.

4. Irritation from (a) hydrocarbons, (b) war gases, especially phosgenes, (c) silicosis, and (d) tobacco smoke.

5. Physical agents: (a) x-ray, and (b) radium.

In a review of cancer of the lung occurring in radium ore miners of Jackymov in a two-year period made by Pirchan and Sikl, and in a similar review of the miners at Schneeborg in Saxony made by Schmorl, no alveolar-cell carcinoma was found in 9 miners who died of cancer of the lung. Anthracosis and pneumoconiosis apparently were not factors.

Biologic Studies in Primary Adenomatosis.—Attempts to culture a virus in laboratory animals have been fruitless in the experience of a number of investigators.

1. Dr. Jonas Salk conducted a number of virus studies with sputum from one of my patients with proved alveolar-cell carcinoma, using monkeys and guinea pigs in his laboratory at the University of Pittsburgh. He failed to find any evidence of a virus at work.

2. Clagett ground up tumor and injected the emulsion into sheep, rhesus monkeys, into 2 dogs, and the internal chamber of the eyes of 5 guinea pigs. There was no growth in four months. He did not rule out the possibility of a virus at work.

3. Dungal reported one case of experimental transmission by extrapulmonary injection of tissue suspension.

4. Grumbach produced diffuse epithelization in the lung after injection of the gall bladder with diptheroid bacilli obtained from a lymph gland of a patient with Hodgkin's disease.

5. Grady and Steward, by subcutaneous injection of 1, 2, 5, 6—dibenzanthracene in mice, produced malignant tumors of alveolar origin not associated with inflammatory reaction. These tumors were little different from those appearing in human beings, and were multicentric with predilection for peripheral zones of the lung. Cells were observed scattered in small foci close to the pleura preceding the development of tumor nodules, and also closely adjacent to peripheral zones for expanding tumors, and were indistinguishable from alveolar phagocytes. In the early stages, there was no active proliferation of these cells, only progressive swelling and enlargement. In the later stages, mitotic division occurred in cells adjacent to the tumor, and in the tumor cells themselves. In the latest stages, there was complete investment of alveolar walls by a layer of cuboidal cells which morphologically appeared epithelial. They concluded, therefore, that alveolar lining cells, whatever their embryological origin, might be capable of differentiating into cells indistinguishable from an alveolar phagocyte, and later into an alveolar tumor cell.

6. Norris injected fluid aspirated from a patient with lobar pneumonia into a guinea pig. One lung developed a zaagsiekte-like lesion.

7. Sims inoculated animals with a 10 per cent suspension of tumor tissue mass; 1 monkey, 6 c.c. intranasally; 2 rabbits, 3 c.c. intrapulmonically; 1 guinea pig, intrapulmonically; 2 guinea pigs by 25 c.c. of atomized spray for a six-hour period in a closed chamber. In none of these animals was there evidence of tumor transmission.

Pathology.—Alveolar-cell carcinoma does not resemble any other growth. It appears grossly in two forms: (1) nodular, multiple growths distributed throughout one or both lungs, and (2) a diffuse form suggestive of coalescence of the nodules. Both forms may occur at the same time. The nodules are miliary to marble size; yellowish-gray, whitish or pink in color; globular, firm, and with fairly sharp borders. The diffuse form resembles a pneumonia in a stage of gray hepatization involving a lobe or even an entire lung. Even so, the appearance suggests an enlargement from multiple foci. Intervening tissue may exhibit varying digrees of inflammation and necrosis. There may be unilateral or bilateral pleuritis with fibrinous or serous exudate and adhesions of varying density. Cavities and bronchiectasis are rare. There is no involve-

ment of bronchi or bronchioles with tumor. The lungs are increased in weight. In general, the changes in the lungs were more extensive than physical signs or x-ray appearance indicated.

Metastases are not a prominent or early feature. They occurred in about 45 per cent of the cases; in 53 of 117 autopsies. Apparently, the incidence and extent of metastases are proportionate to the duration of the disease, being less in acute cases of short duration. Metastases extend by the lymphatics or blood stream in order of frequency into tracheobronchial (hilar) lymph nodes, the pleura, distant lymph nodes, pericardium, liver, kidneys, adrenals, brain, and skeletal system. In Table I are recorded findings in 117 autopsies.

TABLE I. FINDINGS IN 117 AUTOPSIES

One lung involved	30
One lobe involved	11
Both lungs involved	87
Pleural fluid	13
Metastases.—53 cases	
Lymph nodes	38
Hilar (tracheobronchial)	27
Mediastinal	11
Cervical	11
Retroperitoneal	3
Pancreatic	1
Thoracic	15
Pleura	9
Pericardium	7
Heart	3
Diaphragm	3
Abdominal	24
Adrenal gland	18
Liver	11
Kidney	8
Spleen	1
Pancreas	1
Omentum	2
Brain	5
Thyroid	1
Skeleton	8
Sternum	3
Ribs	4
Spine	6
Pelvis	1
Long bones	6

Microscopically.—The prominent feature is that the interalveolar septa are lined but not invaded by columnar cells which show all degrees of proliferation and form papillary projections into the alveolar lumen. The cytoplasm of the cells is clear; may be pink staining due to the secretion of a considerable amount of mucus. Nuclei vary in size as do the cells themselves.

Opinion differs as to the origin of these cells; whether they come from the alveolar lining epithelium, from the basal cells of the respiratory bronchioles, or from the mesenchymal septal cells. This matter is amply discussed by Drymalski and Geever, and Neubuerger and Davis. Anatomical developmental studies seem to fortify the opinion that the alveoli are saccular outgrowths of bronchioles and are originally lined by continuous cuboidal epithelial layers. In the late intrauterine stage, the capillary bed develops extensively, interrupting and breaking

through the epithelial lining, leaving the epithelium as isolated rounded cells, few in number. Thus, the alveolar lining disappears by disintegration, a physiological phenomenon to allow more rapid interchange of gases between alveoli and blood vessels. The postnatal bronchial epithelium appears to terminate more or less abruptly at the beginning of the alveolar walls which are composed of capillaries in delicate reticular and elastic stroma. In the walls are scattered so-called septal cells of mesenchymal origin (epicytes of Clair and Macklin, alveolar cells of Lang). These are fairly characteristic cells with large, oval, pale vesicular nuclei, and abundantly clear cytoplasm which is irregular in contour. They are, in turn, capable of proliferation and transformation (Oppenheim) into epithelial cellular elements. From a practical standpoint, the embryological or histological origin of the alveolar cells is not at all important.

Clinical Features in 155 Cases.—It should be stated that a number of reports do not contain complete clinical data. Incidence is in ratio of 3 males to 2 females; 92 males, 63 females. Only 2 cases occurred in Negroes; 1 in a Japanese. The youngest patient was a 17-year-old girl and the oldest was an 83-year-old woman. The peak is reached in the sixth decade. Table II records the age incidence.

TABLE II. INCIDENCE

AGE	NO. OF PATIENTS	SEX	
10-20	1	Male	92
21-30	6	Female	63
31-40	23		
41-50	32		
51-60	58		
61-70	20		
71-83	15		

The family history in the series was not significant, nor was occupation. Two men were subjected to dusty atmospheres, one of these was a molder. Another patient was a sheep rancher, and another a dairy farmer. There was little or no reference to the use of tobacco. Trauma to the chest was considered a possible factor in 1 case.

The past history was not enlightening. Previous respiratory infection was recorded in 18 cases. It was diagnosed as bronchitis in 4 cases; influenza in 5; pneumonia in 3; pleurisy in 2; sinusitis in 3; and tuberculosis in 1. There was a history of repeated infections of an influenzal type over a period of fifteen years in 1 case; of syphilis in 2 cases; 4 had had gastrointestinal disease; 2, heart disease; 1, pericarditis; 3, arthritis; 2, gallbladder disease; and, 1, thyroid disease. Two patients had associated cancer, one uterine and the other a concomitant skin cancer of the face.

The onset in the majority of cases was gradual, but in 22 cases it was ushered in by an acute respiratory attack, diagnosed variously as pneumonitis (12), bronchitis (4), pleurisy (2), influenza (1), rhinitis and sinusitis (4). In 2 cases, the disease was asymptomatic and discovered only in the course of routine physical check-up. The earliest and most constant symptom was a cough and in all but 9 cases was productive of sputum. The sputum was characteristically thin, watery mucoid, white at times, foamy or purulent. The amount

varied from 30 c.c. to 1,500 c.c. in twenty-four hours. In only 4 cases was the sputum scanty. Dyspnea was a feature in 81 patients; it was of all grades, usually present only on exertion, but described as severe by 7. Once developed, it was likely to be progressive. Weight loss and fatigue were not prominent features. Cyanosis was present in 20 patients; hemoptysis in 13; streaking of sputum in 4. Fever was recorded in 20 per cent of the cases and apparently accompanied definite infection of the lung. Once the symptoms developed there was no letup, and the clinical condition deteriorated progressively, slowly or rapidly until death, except in those cases relieved by surgery. The deterioration was hastened by intercurrent episodes of infection of the lung, and by development of metastases. These often added symptoms peculiar to their location as, for example, cerebral disturbance in brain lesions. Death came from asphyxia due to replacement of respiratory epithelium, heart failure, or from complicating pulmonary infection.

The duration of illness, until a patient came under hospital observation, varied from a matter of several weeks in 9 cases, to five years in 2 cases, and six years in 1 case. In 80 per cent, or 123 cases, the duration was less than a year. Most of the patients when admitted for institutional care or study were gravely ill and died within six months.

Physical signs were dependent on the underlying pathological condition in keeping with the degree of infiltration, consolidation, or pleural effusion. Percussion note was that of impaired resonance, dullness or flatness. Breath sounds were diminished, occasionally bronchial in quality and at times absent. Râles were a more constant finding, of a subcrepitant rather than crepitant type; occasionally sibilant or fairly moist and described as bubbly. In several patients who had major heart lesions, the pulmonary signs were overshadowed by edema of congestive heart failure.

The blood picture changed with the duration of the disease and the degree of infection. In general, anemia was not a factor. In only 3 cases was there a red cell count of less than 4.0 million and hemoglobin of less than 70 per cent. One of these was found to have only 4.6 Gm. hemoglobin and a count of 600,000 cells. A primary anemia had been diagnosed ten years before. With appropriate treatment the blood count rose to 4.0 million cells in two weeks. In contrast, 5 patients had 5.0 million cells with a hemoglobin of more than 90 per cent, 100 per cent, and 104 per cent. The white blood counts were evenly divided into two groups; one with a count of 5,000 to 10,000 and the other with a count of 10,000 to 20,000 per cubic millimeter. In only 4 cases was the count more than 20,000. Polymorphonuclear cells ranged between 80 per cent and 90 per cent among the highest cell counts; 54 per cent to 80 per cent in the lower. Leukocytosis was usually indicative of associated acute inflammation.

Sputum examination for malignant cells was recorded as having been made in 42 cases and found positive in 18. Malignant cells were recorded 5 times from pleural fluid; 3 times by aspiration biopsy of the lung; and 4 times in cervical lymph glands.

By x-ray examination, the earliest lesions appeared as light, patchy infiltrations. Later came nodular lesions which were seldom solitary and usually multi-

centric, often coalescent to the point of forming a mass or massive pneumonic consolidation. Pleural fluid was present in 10 per cent of the cases, ranging in quantity from a small amount to a chest full. In only several cases was atelectasis present. Enlargement of the hilar lymph glands was infrequent. The lesion was demonstrated in one lung 92 times; one lobe 31; as a solitary nodule in 4; and a solitary mass in 5. The x-ray appearance was not pathognomonic of alveolar-cell carcinoma. It was not to be distinguished definitely from adenocarcinoma, metastatic carcinoma, primary tuberculosis, sarcoid granuloma, fungus disease, or bacterial pneumonitis. Therefore x-ray examination of itself was of little aid in establishing the diagnosis of alveolar-cell tumor.

Bronchoscopy and bronchography proved of little value in 21 cases except in a negative way. No tumors were seen in the accessible bronchi. Inflammatory reaction was observed occasionally and some anatomic narrowing or bulging, but no ulceration. Occasionally there was a suggestion of a bronchorrhea.

Differential Diagnosis.—The diagnosis of alveolar-cell carcinoma is difficult to make during life. It can be established with certainty only if characteristic tumor cells are found in either the sputum or pleural fluid by biopsy of lung tissue, secured by aspiration at the time of exploratory thoracotomy, or by biopsy of involved cervical lymph nodes. In the series it was usually established only at autopsy. Alveolar-cell carcinoma was diagnosed correctly in only 32 cases before death, although carcinoma was diagnosed in 23 additional cases. The other diagnoses, preoperatively or ante mortem, were pneumonitis, 21 cases; tuberculosis, 14 cases; pulmonary suppuration, 5; chronic fibrosis, 3; pulmonary edema, 2; sarcoid, 2; metastatic carcinoma, 5; fungus, 3; Hodgkin's disease, 1. In the absence of positive findings, the differential diagnosis hinges on the process of exclusion, for example, by not finding a tubercle bacillus or a fungus in the sputum. Confusion arises because pulmonary disease may be coexistent with the tumor, and may overshadow it. Coccidioidosis may be diagnosed by a positive skin test; histoplasmosis also by a skin test, or by a positive blood culture of *Histoplasma capsulatum* in its yeast phase. Sarcoidosis is a localized lesion involving tracheobronchial and paratracheal lymph nodes without lack of debilitation. Leukemia has a characteristic blood picture, and usually a fine miliary stippling in x-ray appearance. Xanthomatosis usually shows fibrotic and emhysematous components in the x-ray. Secondary neoplasms can be differentiated by cell study and the findings of the extrapulmonic lesions. Hodgkin's disease can be diagnosed by lymph node biopsy.

Treatment.—Inasmuch as alveolar-cell tumor is a malignant neoplasm, treatment other than by radiotherapy and surgery can be at best only palliative. Antibiotics and chemotherapy have their place in relieving the severity of the infection in the bronchi and alveoli, in those cases complicated by bronchiectasis and pneumonitis, and particularly in pneumonitis which often initiates the clinical symptoms. Nitrogen mustard was tried in 5 terminal cases without benefit, but perhaps it has not had sufficient trial. Medical treatment otherwise must be symptomatic to relieve cough, pain, hemoptysis, and to aid digestion and nutrition.

X-ray treatment has been given in 16 cases, in most of them as a palliative procedure. None of these patients recovered but there is evidence that radiotherapy may slow the progress of the disease, as in 1 case that I am reporting. There was no evidence that it had prevented the development of metastases. Used in 3 cases after surgery, one of these was alive and well after five years, after a lobectomy, followed by a pneumonectomy; another was alive after four months; the third was dead in six months. This is too small an experience upon which to establish the value of radiation as a postoperative procedure. It would be definitely hazardous to employ x-ray to the exclusion of surgery even in early lesions of small extent. Alveolar cell carcinoma is apparently not sensitive to x-rays.

Surgery, then, is the only method of treatment which offers a chance for recovery, as is true in bronchogenic carcinoma, but probably is not as successful because of the proclivity for alveolar-cell carcinoma to be multicentric and often bilateral in its early stages.

Results of Surgical Treatment in 50 Cases.—Exploratory operation was performed in 10 cases; segmental resection in 4; lobectomy in 18; lobectomy and lingulectomy in 1; pneumonectomy in 17; exploratory biopsy by needle in 4. Of these 50 cases operated upon, 11 patients are known to be living and well for a period of one to ten years; 1 for six years; 2 for five; 5 for four; 1 for as long as ten years; and one longer than two. Five of these 11 had pneumonectomies, and three had lobectomies. There were 8 postoperative deaths. Eleven died within six months; 4 within twelve months, 8 within two years, and 2 within four years. One was lost to follow-up.

These results are probably no better than, if as good as, those following surgery for adenocarcinoma or squamous-cell carcinoma of bronchial origin. While it is inadvisable to make deductions from a small series, the statistics indicate that pneumonectomy is the operation of choice. Segmental resection or lobectomy should be reserved for those occasoinal cases where there is a localized minimal lesion. Opportunity for resection surgery will depend upon early recognition of the tumor. Improvement in recovery statistics will also depend upon early surgical attack. That a number of these cases have had symptomatic relief and their lives have been prolonged or made more comfortable justifies surgical treatment, but resection for palliation only is questionable.

CASE REPORTS

CASE 1.—M., a 49-year-old man who was born and raised on a farm, had had practically nothing to do with animals or sheep since boyhood. Four years before he remembered having inspected a flock of sheep, but was exposed to them only for a matter of an hour or so. He was employed in a grocery business. In 1919, he was shot in the chest in a hunting accident. The bullet mushroomed, split, and left some fragments in the chest, but he made a satisfactory recovery in a month's time. In 1934, the larger bullet fragment was removed from the ensiform cartilage, but small fragments were left in the chest. He had had arthritis in the neck for fifteen years following a dental abscess. In 1940, he had had double pneumonia which was treated with sulfonamides and he made a satisfactory recovery. In 1946, he developed indefinite pains in the chest, and a roentgenogram made then did not show any abnormality. In September, 1947, he was reaching over to pick a 10

Fig. 1.—Case 1. E. M. Left lung showing a nodule and diffuse infiltration in upper lobe and, likewise, in lower lobe.

Fig. 2.

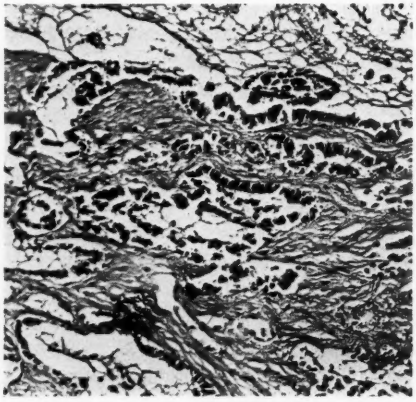
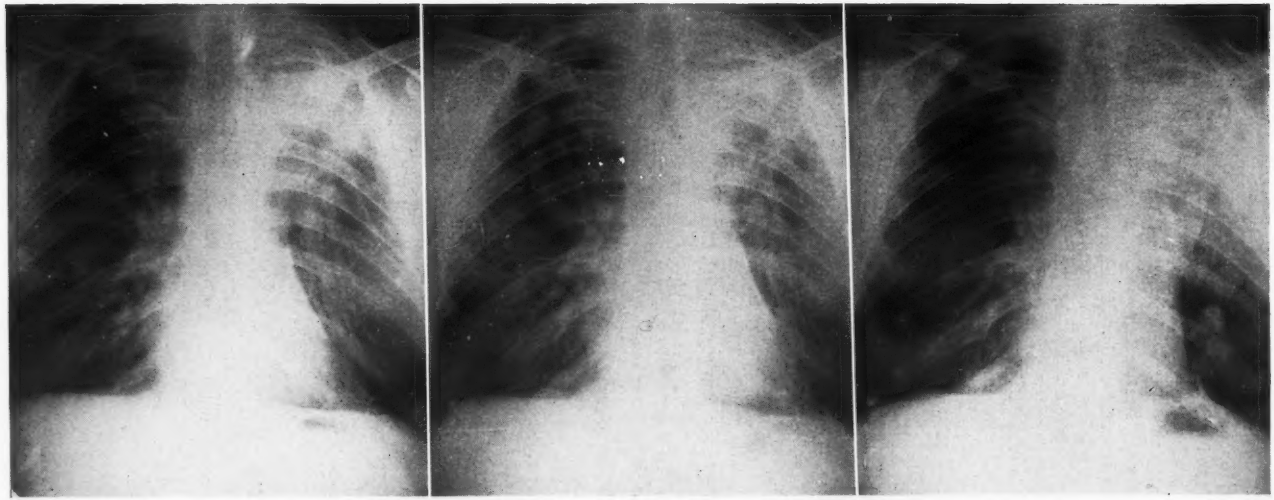


Fig. 3.

Fig. 2.—Case 1. Left temporal lobe of brain showing a large tumor mass with central necrosis.

Fig. 3.—Case 1. Photomicrograph of the lung tumor showing tall columnar cells in papilla-like projections enclosing spaces filled with mucus. (×20; reduced ⅕.)



A. *B.* *C.*

Fig. 4.—Case 1. Roentgenograms showing appearances of tumor treated by x-ray.
A, October, 1949. Extensive consolidation of left upper lobe. Some infiltration in left lower lobe. Few nodules at hilum in lower lobe right lung.
B, September, 1950. Area left upper lobe smaller, less dense. Also, infiltration in lower lobe and right lower lobe.
C, February, 1951. Area upper lobe larger, also nodules in lower lobes.

pound weight off the floor when he had hemoptysis of more than a cup. He was hospitalized and within two or three days had recurrent hemoptysis of about the same amount. The diagnosis was pneumonia. He was treated with penicillin and sulfonamides for several weeks but was left with a cough and shortness of breath. In February, 1948, he was hospitalized at the Research Hospital in Chicago where x-ray showed the probability of a tumor of the lung. Bronchoscopy was attempted but was not carried out because of rigid arthritis in the neck. He was given three x-ray treatments over a period of two days, and it was thought that these treatments caused some recession of the tumor, though shortness of breath and a moderate amount of white sputum persisted. The patient gained weight up to 233 pounds and then he dieted and reduced to 180 pounds. In December, 1948, he developed clubbing of the fingers, and a certain amount of dizziness and palpitation. He was examined by Dr. W. M. Cooper who found dullness in the upper left chest and, by x-ray, an upper lobe mass. Vital capacity was 3.4 L., 75 per cent of normal. There was some enlargement of the liver. The blood pressure was 130/80; blood count: hemoglobin 90 per cent, R.B.C., 4.96 million, W.B.C., 14,900 per cubic millimeter, hematocrit 38, polymorphonuclear leukocytes 58 per cent, lymphocytes 38 per cent, eosin, 4 per cent. The sputum was negative for tubercle bacilli. On Feb. 19, 1949, he was admitted to my care at the Presbyterian Hospital at which time he had 150 c.c. mucoid sputum daily, and some left subcostal pain. Examination disclosed dullness over the left upper lobe, and x-ray showed consolidation of the lobe. The sputum contained no tumor cells, and bronchoscopy showed no tumor cells. The R.B.C. was 4.5 million; hemoglobin 93 per cent; weight 200 pounds. The diagnosis was carcinoma of the lung. Exploratory thoracotomy revealed a large mass in the upper lobe adherent to pleura, and smaller nodules in the upper portion of the left lower lobe. The biopsy showed alveolar-cell carcinoma. The sputum and dyspnea were markedly less when he was treated with Aureomycin. X-ray treatment was kept up until December, 1950, when he developed headache and dizziness. After an exploratory craniotomy performed in March, 1950, he was found to have brain metastasis. He died eighteen months after the onset of pneumonia in 1949, and one year after diagnosis of alveolar-cell carcinoma was established.

CASE 2.—D. A., a 66-year-old man, was admitted to my service at the Presbyterian Hospital with a fairly nonproductive cough, progressive loss of weight (15 pounds), and loss of strength. The sputum was negative for tumor cells. Bronchoscopy was negative. X-ray showed a 6 cm. mass in the right upper lung. The diagnosis was carcinoma of the lung and chronic pulmonary fibrosis. A right pneumonectomy was performed and he died thirty-six hours after the operation from asphyxia due to a massive plug in the left main bronchus. The microscopic diagnosis was alveolar-cell carcinoma.

CASE 3.—W. H., a 58-year-old man, had had a cough for five or six years. The sputum was mucoid. There was a 20 pound weight loss, and substernal pain, and x-ray had showed spots on the lungs three years before admission. Bronchoscopy was negative. An x-ray on admission showed extensive nodulation and infiltration of both lungs. The diagnosis was pneumoconiosis and tuberculosis. Malignancy was not ruled out. He died four months after hospital admission, and autopsy disclosed alveolar-cell carcinoma. One bronchial lymph node was involved.

CASE 4.—M. M., a 64-year-old man, was first admitted on April 28, 1950. Two months before, there was an onset of dyspnea on exertion and nausea after eating with a loss of weight of 10 pounds. There was an apical systolic heart murmur and the blood pressure was 125/85. In the right upper lobe there were diminished breath sounds and dullness with a few crepitant râles on coughing. The sputum was negative for tubercule bacilli and there was predominance of gram-positive cocci in chains. The sedimentation rate was 16 mm. in sixty minutes. The hematocrit was 43 per cent. X-ray showed generalized nodular infiltration involving both lungs, with nodules averaging 5 mm. in diameter. One consolidation area was located in the middle of the right lung around the hilus. The diagnosis was silicosis and atelectasis of the right lung. Tuberculosis and carcinoma were not ruled out. On the second admission, June 15, 1950, the x-ray appearance was as before with addition of fluid in the right chest. The fluid, blood tinged, was negative for malignant cells. The diagnosis

was probable carcinoma of the lung. The patient died on July 16, 1951. The autopsy disclosed columnar-cell carcinoma, variant of pulmonary adenomatosis. There was metastasis to the pleura, chest wall, pericardium, mediastinum, tracheobronchial lymph nodes, and omentum. There was 2,000 c.c. of fluid in the pleural space.

Fig. 5.—Case 5. M. L. Left lung partly hemisected showing diffuse distribution of tumor as light mottled areas over the entire surface.

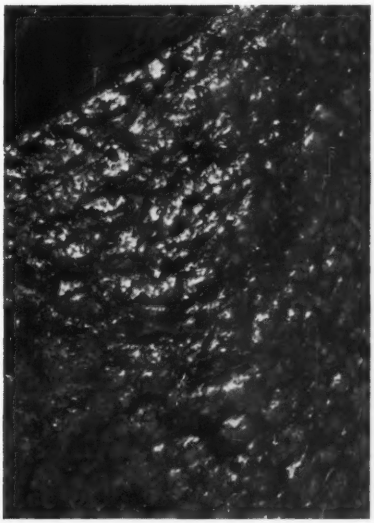


Fig. 6.—Case 5. Close-up of pleural surface.

CASE 5.—M. L., a 39-year-old woman, had had a cough for one year with easy fatigability and dyspnea for six months. She was admitted to the tuberculosis hospital in August, 1949. The sputum was negative for tubercle bacilli. There were cyanosis and substernal pain with a 45 pound weight loss. There was slight hemoptysis one month before. Fine

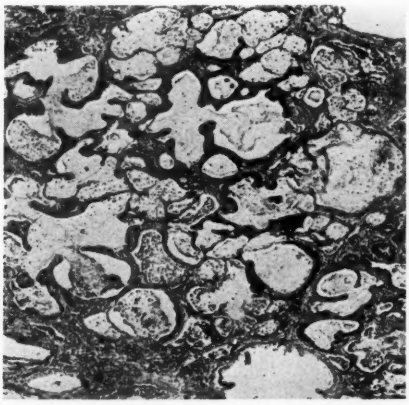


Fig. 7.—Case 5. Photomicrograph of tumor in lung showing large mucus-filled spaces lined by columnar cells. (×120; reduced ⅙.)

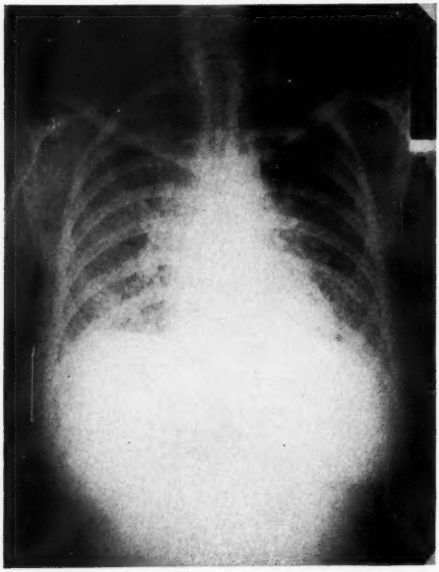


Fig. 8.—Case 5. Roentgenogram, widespread nodules. Infiltration throughout both right and left lung fields.

râles were heard in the bases of both lungs. There were cardiac enlargement and clubbing of the fingers. The blood pressure was 142/90. The vital capacity was 32 per cent of normal. The x-ray showed densities throughout the lung fields except in the apices. The x-ray diagnosis

was pulmonary fibrosis, congestion, and atelectasis due to cardiac failure. The patient grew progressively worse and she died on Jan. 13, 1950. Before her death, there was a diagnosis of a nonsuppurative inflammatory process. Autopsy disclosed columnar alveolar-cell carcinoma.

CASE 6.—W. C., a 35-year-old man had had a productive cough for seven years with occasional aching pain in the chest. A diagnosis was made of minimal chronic pulmonary tuberculosis, arrested. The sputum was negative for tubercle bacilli. There was progressive loss of weight, fatigue, and dyspnea. The x-ray revealed apparent activity as soft densities were present in the right lung field with atelectasis in the left lung. Weakness and muscle cramps developed in the legs and, finally, paraplegia. X-ray showed a destructive lesion of the third dorsal vertebra. The sputum was negative for neoplastic cells. The patient died in October, 1951. Autopsy disclosed alveolar-cell carcinoma with metastasis to the spine, and right clavicle. There was a small healed scar of tuberculosis in the left first interspace.

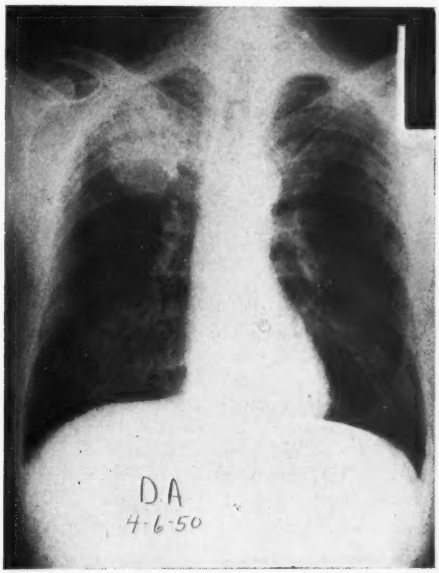


Fig. 9.—Case 2. D. A. Roentgenogram, circumscribed dense shadow characteristic of tumor occupying greater part of right upper lobe.

CASE 7.—M. B., a 49-year-old man, had had a cough for one month which he thought was due to a cold for which he was given penicillin. The sputum was thin, mucoid and negative for tubercle bacilli and malignant cells. The culture showed a predominance of gram-positive cocci. Mycelial forms and Leptothrix were present. The patient had slight dyspnea with a dull aching in the chest. There were no physical abnormalities. The temperature was 99° F., pulse, 90, and respiration, 20. Bronchoscopy showed an upper lobe tumor of the left lung which was beyond the reach of the bronchoscope. X-ray disclosed a large mass in the left paratracheal position. At operation a mass the size of a baseball was seen which involved the left upper lobe medially. Several subpleural nodules were adherent to and penetrating the pleura. The lesion was considered irremovable. The biopsy proved alveolar columnar-cell carcinoma. The patient died within six months.

CASE 8.—A. A., a 53-year-old man, sought medical advice because of swelling of the terminal phalanges of the hands, feet, and ankles, typical of pulmonary osteorathropathy. There were no pulmonary symptoms. Temperature, pulse, and respiration were normal. Examination

of the chest was normal. The blood pressure was 150/90. The sputum was negative for tubercle bacilli and tumor cells. The red blood count was 4.0 million; hemoglobin 83 per cent; w.b.c., 4,500, monocytes 54 per cent. An x-ray examination showed a solitary nodule in the apex of the right lung. Bronchoscopy was negative. A pneumonectomy was performed. The diagnosis was alveolar-cell carcinoma. For two years, the patient has been alive and well.

CASE 9.—J. K., a 51-year-old woman, was admitted to the hospital because of an acute thrombophlebitis in the left leg of two weeks' duration. For ten years previously, she had a known myocarditis with dyspnea and a cough. The sputum was scanty and of the mucoid type. On physical examination subcrepitant râles could be heard at the bases of both lungs. The heart was enlarged with an apical systolic murmur. The blood pressure was 122/82; temperature, 100° F.; pulse, 100; and respiration, 30. The x-ray showed that nodular infiltration was extensive in both lungs with coalescence in the left lower lobe which was almost solid. The nodules varied from 3 mm. to 2 cm. in diameter. The sputum was negative for tubercle bacilli, with staphylococcus predominating. The red blood count was 4.5 million; hemoglobin, 80 per cent; w.b.c., 20,000. She grew progressively worse with increasing cyanosis and dyspnea. Death occurred three months after hospital admission. The diagnosis had been metastatic malignancy, and the autopsy proved it to be alveolar-cell carcinoma, with metastasis in the tracheobronchial lymph nodes. There was an infarct in the spleen and there was thrombosis of the pelvic vessels. The heart showed mitral vegetative endocarditis, and hypertrophy of the right ventricle. Adhesive pleuritis was present.

CASE 10.—H. F., a 55-year-old man, was well until March, 1952, when he developed a cold and malaise following a squeezing injury to the chest. He had a small hemoptysis, and started to lose weight. The cough persisted and dyspnea developed. He was admitted to the hospital in April, one month later. Physical signs in the chest indicated a pleural effusion. The expansion of the right chest was small. Breath sounds were absent with flatness. The liver was enlarged. The temperature was 100° F.; pulse, 90; and respiration, 22; r.b.c., 4.8 million; hemoglobin, 96 per cent; w.b.c., 11,100; polymorphonuclear leukocytes, 74 per cent. The sputum was negative for tubercule bacilli and tumor cells, and gram-positive cocci predominated. The pleural fluid contained no tumor cells. The sedimentation rate was 38 in sixty minutes. The x-ray showed a consolidation of the upper and lower right lung fields, with pleural effusion. Bronchoscopy was negative. An exploratory thoracotomy disclosed a nodular infiltration of the right lower and middle lobes with the lung adherent to the chest wall. Biopsy proved alveolar columnar-cell carcinoma. The patient died one month after the operation.

CONCLUSION

From this record it is evident that alveolar-cell carcinoma is a rare and highly malignant form of cancer which runs a fatal course within two or three years. It is a tumor which cannot be diagnosed often enough in its early stages to permit early and successful attack. Thus far, surgery, and not radiotherapy, is the only treatment for prolonging and saving life. Two patients have lived longer than five years following resection surgery.

REFERENCES

1. Adler, I.: Primary Malignant Growths of the Lung, New York, 1912, Paul B. Hoeber, Inc.
2. Adler, I.: Primary Malignant Growths of the Lung and Bronchi, Pathological and Clinical Study, New York, Longmans, Green & Co.
3. Alexander, C. M., and Chu, F.: Pulmonary Adenomatosis Complicated by Lobar Pneumonia, Arch. Path. **43**: 92-101, 1947.
4. Atkin, A., and Wagner, D. H.: Primary Carcinoma of the Lung, J. A. M. A. **106**: 587-591, 1936.
5. Bell, E. T.: Hyperplasia of Pulmonary Adenomatosis in Disease, Am. J. Path. **19**: 1901, 1943.

6. Bonne, C.: Morphological Resemblance of Pulmonary Adenomatosis in Sheep (Jaagsiekte) and Certain Cases of Cancer of the Lung in Man, Am. J. Cancer **35**: 491-501, 1938.
7. Bensley, R. D., and Bentley, R. H.: Studies of the Lining of the Pulmonary Alveoli of Normal Lungs of Adult Animals, Anat. Rec. **64**: 41-49, 1935.
8. Bremer, J. L.: Post-Natal Development of the Alveolar in Mammals in Relation to the Problem of Alveolar Phagocytes, Contrib. Embryol. **25**: 83-110, 1935.
9. Bernard, W. G., and Day, D. T.: The Development of the Terminal Air Passages of the Human Lung, J. Path. & Bact. **45**: 67-73, 1937.
10. Bubus, S., and Erwin, J. H.: Pulmonary Adenomatosis. Am. J. Med. **7**: 336-344, 1937.
11. Breise: Zur Kenntnis des primaren lungenkarzinoms mit statischen angaber, Frankfurt, Ztschr. Path. **23**: 48-55, 1920.
12. Casilli, A. R., and White, H. J.: Rare Forms of Malignant Lung Tumors; Report of Three Types, Am. J. Clin. Path. **10**: 623-641, 1940.
13. Cooper, E. R.: A Histological Investigation of the Development and Structure of the Human Lung, J. Path. & Bact. **47**: 105-114, 1938.
14. Cowdry, E. V.: Studies of the Etiology of Jaagsiekte: (1) Primary Lesions, J. Exper. Med. **42**: 323-332, 1925. (2) Origin of Epithelial Proliferation and Subsequent Changes, J. Exper. Med. **42**: 335-346, 1925.
15. Cowdry, E. V., and Marsh, H.: Comparative Pathology of South African Jaagsiekte and Montana Progressive Pneumonia of Sheep, J. Exper. Med. **45**: 571-581, 1927.
16. Dacie, J. V., and Moyle, C.: Malignant Adenomatosis (Alveolar Cell Tumor of the Lung), Brit. J. Tuberc. **36**: 158-165, 1942.
17. Davis, M. W., and Simon, T. R.: Alveolar Cell Tumor of the Lung, Am. Rev. Tuberc. **62**: 594-609, 1950.
18. Dennis, John M., Raby, Wm. T., and Hildenbrand, E. J. C.: Pulmonary Adenomatosis, Ann. Int. Med. **36**: 667, 1952.
19. Delarue, N. C., and Graham, E. A.: Alveolar Cell Carcinoma of the Lung (Pulmonary Adenomatosis, Jagziekte ?), J. THORACIC SURG. **18**: 237-251, 1949.
20. Drymalski, G. W., Thompson, J. R., and Sweany, H. C.: Pulmonary Adenomatosis; a Report of Three Cases, Am. J. Path. **24**: 1083-1093, 1948.
21. Dungal, N.: Epizootical Adenomatosis of the Lungs of Sheep; Its Relation to Verminous Pneumonia and Jaagsiekte, Proc. Roy. Soc. Med. **31**: 447-505, 1938.
22. Dungal, N.: Experiment With Jaagsiekte, Am. J. Path. **22**: 737-759, 1946.
23. Dungal, N., Gilasin, G., and Taylor, E. L.: Epizooticadenomatosis in the Lungs of Sheep, J. Comp. Path. & Therap. **51**: 1-46, 1938.
24. Finley, D., and Parker, R. W.: Case Primary Cylindrical Epithelial Cell Tumor Lung, Lancet **1**: 838, 1877.
25. Fisher, John H., and Holly, W. J.: Primary Alveolar Cell Carcinoma of the Lung, Arch. Path. **55**: 162-170, 1953.
26. Fishman, A. P., Epstein, B. S., and Grauzel, D. M.: Primary Alveolar Cell Carcinoma of the Lung With Pulmonary Sclerosis and Right Heart Failure, Am. Heart J. **30**: 309-313, 1945.
27. Fried, B. M.: Primary Carcinoma of the Lungs, Arch. Int. Med. **35**: 1-41, 1925.
28. Fried, B. M.: Primary Carcinoma of the Lungs, Medicine **10**: 373-508, 1931.
29. Freedman, B.: Pulmonary Adenomatosis. Report of a Case, Am. Rev. Tuberc. **60**: 258, 1949.
30. Frissell, L. F., and Knox, L. C.: Primary Cancer of the Lung, Am. J. Cancer **30**: 219, 1939.
31. Geever, E. F., Neubuerger, K. T., and Davis, C. L.: Pulmonary Alveolar Lining Under Various Pathological Conditions, Am. J. Path. **19**: 913, 1943.
32. Geever, E. F., Carter, H. R., Neubuerger, K. T., and Schmidt, E. A.: Roentgenologic and Pathologic Aspects of Pulmonary Tumors Probably Alveolar in Origin With Report of Six Cases, One of Them Complicated by Torulosis of the Central Nervous System, Radiology **44**: 319-327, 1945.
33. Gazayerli, M.: On the Nature of Pulmonary Lining and the Origin of the Alveolar Phagocyte, J. Path. & Bact. **43**: 357, 1936.
34. Gepts, W.: Pulmonary Adenomatosis; Report of Case Demonstrating Peculiar Histological Changes in Certain Bronchioles, Arch. Path. **52**: 473-479, 1951.
35. Good, C. A., McDonald, J. R., Clagett, O. T., and Griffith, E. R.: Alveolar Cell Tumors of the Lung, Collect. Papers Mayo Clin. & Mayo Found. **41**: 485-492, 1949.
36. Good, C. A., McDonald, J. R., Clagett, O. T., and Griffith, E. R.: Alveolar Cell Tumors of the Lung, Am. J. Roentgenol. **64**: 1-18, 1950.
37. Gordon, A. K.: Note on Case of Primary Diffuse Alveolar Carcinoma of the Lung, Lancet **2**: 501, 1920.
38. Grady, H. G., and Stewart, H. L.: Histogenesis of Induced Pulmonary Tumors in Strain A of Mice, Am. J. Path. **10**: 417-432, 1940.
39. Griffith, E. R.: Alveolar Cell Carcinoma of the Lung. Thesis University of Minnesota, J. Roentgenol. & Rad. Therap. **64**: 1-11, 1950.

40. Geschickter, C. F., and Denison, R.: Primary Carcinoma of the Lung, Am. J. Cancer **22**: 854-877, 1934.
41. Hatfield, W. H., and Hill, J. E.: Pulmonary Adenomatosis With a New Laboratory Finding, Am. J. Roentgenol. **62**: 525-530, 1949.
42. Helly, K.: Ein seltenerprimärer. Lungentumor, Ztschr.-Heilk. **28**: 105-110, Pl. IX, 1907.
43. Herbut, P. A.: Bronchiolar Origin of "Alveolar Cell Tumor" of the Lung, Am. J. Path. **20**: 911-929, 1944.
44. Herbut, P. A.: Alveolar Cell Tumor, Further Evidence of Bronchiolar Origin, Arch. Path. **41**: 175-184, 1946.
45. Hildebrand, E.: Pulmonary Adenomatosis; Report of a Case, Am. Rev. Tuberc. **57**: 281-286, 1948.
46. Ikeda, K.: Alveolar Carcinoma of the Lung, Am. J. Clin. Path. **15**: 50-63, 1945.
47. Jennings, G. H.: Lung Alveolar Tumors. Report of Two Cases, Thorax **3**: 174-184, 1948.
48. King, J. C., and Carroll, D. S.: Pulmonary Adenomatosis; a Report of Four Cases, Radiology **55**: 669, 1950.
49. Kennamer, P. A.: Pulmonary Adenomatosis, J. A. M. A. **145**: 815, 1951.
50. Klotz, M. O.: Primary Carcinoma of the Lung, Am. J. M. Sc. **196**: 436-454, 1938.
51. Kretschmer, W. H.: Ueber das primäre Bronchial und Lungen Carcinom. (Thesis) Leipzig, 1904, B. Georgi. Cited by Weissman.
52. Kent, J. V.: Primary Alveolar Carcinoma of the Lung, Brit. J. Radiol. **24**: 216-220, 1951.
53. Laipply, T. C., and Fisher, E. L.: Primary Alveolar Tumors of the Lung, Arch. Path. **48**: 107-118, 1949.
54. Macklin, C. C.: Pulmonary Alveolar Epithelium, J. THORACIC SURG. **6**: 82-88, 1936.
55. Malassez, L.: Examen histologique d'un cas de cancer encephaloide du poumon (epithelioma), Arch. de physiol. norm. et path. **3**: 353-372, Pl. XIX, 1876.
56. McCallum, R. I.: Alveolar Cell Tumor of the Lung. Report of a Case, Brompton Hosp. Rep. **18**: 140-151, 1949.
57. McCoy, H. I.: Alveolar Cell Carcinoma of the Lung, Ann. Int. Med. **34**: 968, 1951.
58. Miller, James: Primary Carcinoma of the Lung, Am. Rev. Tuberc. **21**: 1, 1930.
59. Miller, W. S.: The Lung, ed. 2, Springfield, Ill., 1947, Charles C Thomas, Publisher.
60. Musser, J. H.: Primary Cancer of the Lung, Univ. Pennsylvania Bull. **16**: 261-265, 1903. Trans. Assoc. Am. Phys. **18**: 624-636, 1903.
61. Neubuerger, K. T.: Primary Alveolar Cell Tumor of the Human Lung. Report of a Case, J. THORACIC SURG. **10**: 557-565, 1941.
62. Neubuerger, K. T., and Geever, E. F.: Alveolar Cell Tumor of the Human Lung, Arch. Path. **33**: 1551-1569, 1942.
63. Norris, R. F.: Pulmonary Adenomatosis Resembling Zaagsiekte in Guinea Pig, Arch. Path. **43**: 53-58, 1947.
64. Osserman, K. E., and Neuhof, H.: Mucocellular Papillary Adenocarcinoma of the Lung and Lobectomy, J. THORACIC SURG. **15**: 272-278, 1946.
65. Paul, L. W., and Ritchie, G.: Pulmonary Adenomatosis, Radiology **47**: 334-343, 1946.
66. Paul, L. W., and Juhl, J. H.: Pulmonary Adenomatosis: Further Roentgen Observations, Radiology **55**: 681, 1950.
67. Peterson, E. W., and Houghton, J. D.: Pulmonary Adenomatosis, New England J. Med. **244**: 429-433, 1951.
68. Pirchan, A., and Sikl, H.: Cancer of the Lung in the Miners of Jackymov (Joachimstahl), Am. J. Cancer **16**: 681-722, 1932.
69. Richardson, G. O.: Adenomatosis of the Human Lung, J. Path. & Bact. **51**: 297-298, 1940.
70. Reuss, H.: Ueber zwei falle multicentrish enstundenen lungen kraher. Inengunl Dissertate. Hamburg, 1934.
71. Rosemond, G. P., Burnett, W. E., and Hall, J. H.: Value and Limitations of Aspiration Biopsy for Lung Lesions, Radiology **52**: 506, 1949.
72. Rosemond, G. P., Boucot, K. R., and Aegerter, E.: Solitary Pulmonary Adenoma (Focal Pulmonary Adenomatosis). A Three Year Follow-up After Resection, J. THORACIC SURG. **22**: 99-103, 1951.
73. Ross, I. S.: Pulmonary Epithelium and Proliferative Reactions in the Lungs, Arch. Path. **27**: 478-496, 1939.
74. Rusk, G. Y., and Randolph, V.: The Anatomic Findings in Cases Simulating Pulmonary Tuberculosis, J. A. M. A. **82**: 442-447, 1924.
75. Simon, M. A.: So-called Pulmonary Adenomatosis and "Alveolar Cell Tumors." Report of a Case, Am. J. Path. **23**: 413-427, 1947.
76. Simon, M. A.: Diffuse Primary Alveolar Carcinoma of the Lung, Am. J. Clin. Path. **17**: 773-776, 1947.
77. Simon, M. A.: Hamartomas of the Lung and So-called Pulmonary Adenomatosis. Am. J. M. Sc. **216**: 333-342, 1948.
78. Simonds, J. P., and Curtiss, J. S.: Lesions Induced in the Lungs by Intravenous Injection of Tar, Arch. Path. **19**: 287-302, 1935.

79. Sims, J. C.: Multiple Bilateral Pulmonary Adenomatosis in Man, Arch. Int. Med. **71**: 403-409, 1943.
80. Smith, R., Knudtson, K. P., and Watson, W. L.: Terminal Bronchiolar or "Alveolar Cell" Cancer of the Lung. A Report of Twenty Cases, Cancer **2**: 972-989, 1949.
81. Straub, M.: Microscopic Changes in Lungs of Mice Injected With Influenza Virus, J. Path. & Bact. **45**: 75-78, 1937.
82. Stephens, H. B., and Shipman, S. J.: Pulmonary Alveolar Adenomatosis; Cancerous Pulmonary Adenomatosis; Alveolar Cell Carcinoma of the Lung, Jaagsiekte?, J. THORACIC SURG. **19**: 589-599, 1950.
83. Strance, J. G.: Pulmonary Adenomatosis and Its Relationship to the Problem of Malignant Tumors of the Lung, Am. Surgeon **18**: 655, 1952.
84. Swan, L. L.: Pulmonary Adenomatosis of Man. A Review of the Literature and Report of Nine Cases, Arch. Path. **47**: 517-544, 1949.
85. Sweeney, H. C.: So-called Alveolar Cell Carcinoma of the Lung, Arch. Path. **19**: 203-207, 1935.
86. Taft, E. B., and Nickerson, D. A.: Pulmonary Mucous Epithelial Hyperplasia (Pulmonary Adenomatosis); a Report of Two Cases, Am. J. Path. **20**: 395-411, 1944.
87. Tillet, R. B., and Hirsch, E. F.: So-called Pulmonary Adenomatosis of the Lung, Illinois M. J. **101**: 53, 1952.
88. Watson, W. L., and Smith, R. R.: Terminal Bronchiolar or "Alveolar Cell" Cancer of the Lung. Report of Thirty-Three Cases, J. A. M. A. **147**: 7-13, 1951.
89. Weir, A. B., Jr.: Pulmonary Adenomatosis. Clinical Review and Report of Three Cases, Arch. Int. Med. **85**: 806-818, 1950.
90. Weismann, S.: Ueber dar diffuse primäre alveolar epithelcarcinom der Lunge. Frankfurt Ztschr. Path. **47**: 534-551, 1935.
91. Weller, C. V.: The Pathology of Primary Carcinoma of the Lung, Arch. Path. **7**: 478-519, 1929.
92. Wenger, F.: Sobre un caso de tumor de las células alveolares del pumón, Prensa méd. argent. **32**: 44-48, 1945. Cited by L. L. Swan.
93. White, J. N., Madding, G. F., and Hershberger, L. R.: Alveolar Cell Tumor of Lung, Dis. Chest **21**: 655, 1952.
94. Winternitz, M. C., Smith, G. H., and McNamara, F. D.: Epithelial Proliferation Following Intrabronchial Insufflation of Acid, J. Exper. Med. **32**: 205-217, 1920.
95. Womack, N. A., and Graham, E. A.: Mixed Tumors of the Lung, Arch. Path. **26**: 165, 1938.
96. Wood, D. A., and Pierson, P. H.: Pulmonary Alveolar Adenomatosis in Man. Is This the Same Disease as Jaagsiekte in Sheep?, Am. Rev. Tubere. **51**: 205-243, 1945.
97. Wood, E. H.: Unusual Case Carcinoma of Both Lungs Associated With Lipoid Pneumonia Radiology **40**: 193-195, 1943.
98. Woolner, L. B., and McDonald, J. R.: Carcinoma Cells in Sputum and Bronchial Secretion, Surg., Gynec. & Obst. **88**: 273, 1949.
99. Young, J. S.: (A) The Experimental Production of Metaplasia and Hyperplasia in the Serosal Endothelium, and of Hyperplasia in the Alveolar Epithelium of the Rabbit. (B) Further Experiments on the Production of Hyperplasia in the Alveolar Epithelium of the Lung of the Rabbit, J. Path. Bact. **31**: 265-275; 705-720, 1928.
100. Young, J. S.: Epithelial Proliferation in the Lung of the Rabbit Brought About by Intrapleural Injections of Solutions of Electrolytes; Physico-Chemical Interpretation of the Phenomenon, J. Path. & Bact. **33**: 363-381, 1930.
101. Zeldes, M.: Alveolar Lining of the Lung in Relation to the Viability of the Fetus, Arch. Path. **29**: 748-758, 1940.

IMPROVED INSTRUMENT FOR TIMED VITAL CAPACITY

J. K. Curtis, M.D., P. E. Sadler, M.D., and H. K. Rasmussen, B.S.
Madison, Wis.

VITAL capacity is one of the oldest measurements of pulmonary ventilation. In recent years the test has been critically analyzed by a number of investigators. Björk[1] and others have suggested that the test be eliminated. The chief count against the test is the wide range of normal values. Formulas for predicting normal vital capacity are available.[2, 4] but a single test may deviate as much as 20 per cent from the calculated figure. On the other hand, serial determinations of the vital capacity are especially useful in evaluating a patient's ventilatory status from time to time. Thus, the observed changes become more important than the single observation or deviation from normal. The validity of serial studies is based on the fact that repeated vital capacity tests from day to day or month to month will yield almost identical results on a normal subject.[5] A series of 24 convalescing tuberculosis patients with stable x-rays were tested in our laboratory and retested after an interval of three months. Our results showed a difference of +3.6 per cent between the averages of the first and second determinations and a range of +11 per cent to –9 per cent. We have used the test extensively for determining the amount of functioning lung lost as a result of pulmonary resection for residual tuberculous disease.[6]

Recently, Gaensler[5, 7, 8] has popularized the timed vital capacity. This is a dynamic test designed to give the amount of the expired air in relation to time. As generally performed, the test gives the amount of air expired in one, two, and three seconds, as well as the total vital capacity, from which the percentages may be calculated. In normal subjects the percentage expired in the first second is 83 per cent, in two seconds 94 per cent and in three seconds 97 per cent.[5] The test is useful in separating patients with obstructive insufficiency from those with restrictive ventilatory insufficiency. For example, the emphysematous patient often has a total vital capacity within normal range, but the timed vital capacity demonstrates prolonged expiration.

At our hospital, patients scheduled for pulmonary resection receive ventilatory screening tests consisting of the spirographic pattern as described by Baldwin,[4] maximum breathing capacity,[4] and one-breath O_2 test for intrapulmonary mixing.[9] During the past year, if the spirogram suggested air trapping or if the maximum breathing capacity was reduced and the tracing showed elevation to hyperinflation level, the Gaensler timed vital capacity test was performed. Under these circumstances the timed vital capacity like-

From the Veterans Administration Hospital, Madison, Wis.
Received for publication Feb. 16, 1955.

wise proved to be abnormal. Furthermore, most of the surgical patients with greatly prolonged timed vital capacity have shown emphysema in the resected portion of the lung.[6]

The vitalometer, as recommended by Gaensler,[7] is a standard Collins vital capacity instrument with a 7 L. bell suspended in a water bath. By means of an electrical device, the amount of air expired on maximum, rapid expiration is determined for one, two, and three seconds. Percentage is calculated by dividing these figures by total vital capacity. We have found the apparatus to be reliable, but there are certain features which are undesirable. First, the apparatus does not measure the time necessary to expel the first 200 to 400 c.c. of air. This is due to the design of the timing device which is not activated until this amount of gas displaces the bell upward. Thus, criterion number 2 of Gaensler[8] is not met. This states that the instrument should permit initiation of the timing cycle by the beginning of the patient's expiratory effort. The speed with which the patient initiates expiration under conditions of work is an important factor in pulmonary ventilation. The maximum breathing capacity is greatly influenced by the rapidity of the initial phase of expiration.[10] A second factor of concern to the patient is the necessity of repeating the test at least two times for each second in order to ensure data with maximum accuracy. This is not only tiring to some patients but consumes the technician's time. Third, the apparatus provides no spirographic record for future study and comparison.

These difficulties may be overcome by adapting a recording system to the vitalometer. A low torque potentiometer* is fitted over the shaft of the pulley wheel (Fig. 1). The activating current is obtained from a 1.5 volt battery connected to a rheostat. The output of the potentiometer is led to a D.C. amplifier in a Sanborn recorder run at a speed of 2.5 cm. per second. Fig. 2 shows the electrical diagram. The curve obtained is practically linear (Fig. 3), and gives the volume of expired air in relation to time. Calculation of the timed vital capacity is easily accomplished by reading the volumes for each second off the curve after projecting perpendicular lines for one, two, and three seconds from the time line. Fig. 4, *A* illustrates a normal vital capacity curve. On the ordinate at the left is shown the standardization of 0 and 5,000 c.c. Five large squares along the base represent one second. Fig. 4, *B* shows an abnormal curve obtained from a patient with pulmonary emphysema, proved by resection of the lung.

To ensure accuracy, the apparatus was tested for resistance to rapid air flow and this was found to be negligible (2 cm. of water pressure at rate of 6,000 c.c./sec.). Thirty patients with vital capacities varying between 1,500 c.c. and 5,000 c.c. were selected to perform the vital capacity test on the vitalometer, on a Collins respirometer, through a high velocity valve into a meteorological balloon, and on a special Emerson low resistance gas volume meter. Care was taken to vary the sequence in which the four instruments were used. No corrections for temperature, pressure, and humidity were made as the four tests on each individual were performed under the same conditions. Table I shows the results of these tests. It is evident that the vitalometer

*Giannini No. 2, 270 degrees, low torque, 100,000 ohm.

yields accurate results in all clinical ranges. Furthermore, duplicate volume curves were carried out on 30 patients, allowing a few minutes between the first and second test. There was very little difference between the first and second total vital capacity tests. The correlation coefficient (r = .97) between these indicates a high degree of reliability between repeated testings. The differences between the duplicate values obtained for the first, second, and

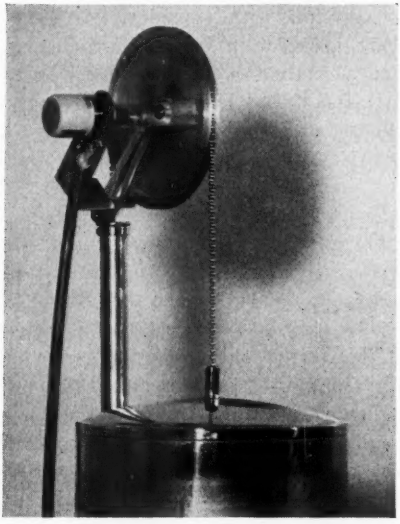


Fig. 1.—Potentiometer fitted to vitalometer.

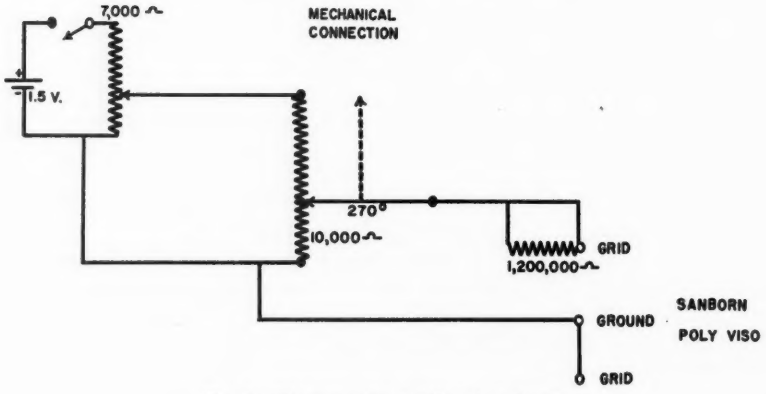


Fig. 2.—Diagram of potentiometer circuit.

third second timed vital capacity were likewise extremely small. When subjected to statistical analysis, the correlation coefficient for the first second was r = .95, second second, r = .97, and third second, r = .95.

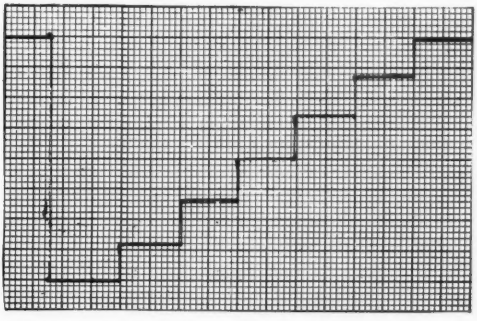


Fig. 3.—Each step represents addition of an equal amount of gas to vitalometer.

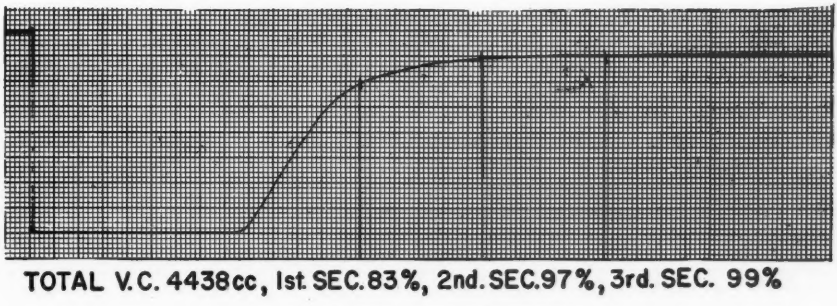


Fig. 4*A*.—Normal timed vital capacity.

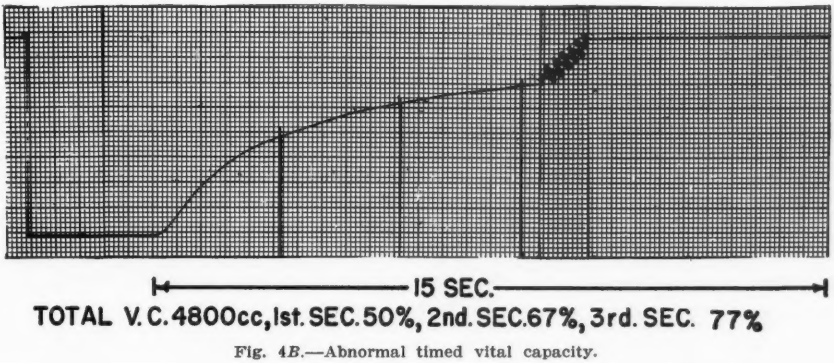


Fig. 4*B*.—Abnormal timed vital capacity.

TABLE I. COMPARISON OF FOUR TYPES OF VITAL CAPACITY INSTRUMENTS

AVERAGE VITAL CAPACITIES	NO. OF PATIENTS	VITALOMETER	RESPIROMETER	EMERSON	BALLOON
	30	3,748 c.c.	3,530 c.c.	3,583 c.c.	3,747 c.c.
Group 1. 1,500-3,000 c.c.	8	2,621	2,427	2,456	2,556
Group 2. 3,000-4,000 c.c.	8	3,368	3,247	3,218	3,415
Group 3. 4,000-5,000 c.c.	14	4,609	4,322	4,427	4,617

SUMMARY

1. The value of the vital capacity test for evaluating changes in pulmonary ventilation is discussed.
2. A modification of the vitalometer is described which utilizes a potentiometer to obtain a timed volume graph.
3. The advantages of this modification are as follows:
   a. The method records air flow from the moment expiration begins.
   b. Only one expiratory effort is required to obtain data from which one-, two-, and three-second timed vital capacity percentage is calculated.
   c. A small permanent record is obtained which is accurate and easily interpreted.
4. The convenience and simplicity of this instrument extend the usefulness of the timed vital capacity in screening patients before pulmonary surgery.

REFERENCES

1. Björk, V. O.: Cardiopulmonary Function Tests, J. THORACIC SURG. **26**: 67, 1953.
2. West, H. F.: Clinical Studies on Respiration: VI. Comparison of Various Standards for Normal Vital Capacity of Lungs, Arch. Int. Med. **25**: 306, 1920.
3. Myers, J. A.: Vital Capacity of Lungs, Baltimore, 1925, Williams and Wilkins Company.
4. Baldwin, E. D., Cournand, A., and Richards, D. W., Jr.: Pulmonary Insufficiency: I. Physiological Classifications, Clinical Methods of Analysis, Standard Values in Normal Subjects, Medicine **27**: 243, 1948.
5. Gaensler, E. A.: Analysis of the Ventilatory Defect by Timed Capacity Measurements, Am. Rev. Tuberc. **14**: 256, 1951.
6. Unpublished data.
7. Gaensler, E. A.: An Instrument for Dynamic Vital Capacity Measurements, Science **114**: 444, 1951.
8. Gaensler, E. A.: Laboratory and Other Basic Research, Analysis of the Ventilatory Defect by Timed Capacity Measurements, Tr. 47th Ann. Meet. Soc. NTA, 1951.
9. Comroe, J. H., Jr., and Fowler, W. S.: Lung Function Studies: VI. Detection of Uneven Alveolar Ventilation During a Single Breath of Oxygen; a New Test of Pulmonary Disease, Am. J. Med. **10**: 408, 1951.
10. Van Veen, G., and Hirdes, J. J.: Spirometric Lung Function Investigations: II. The Form of the Expiration Curve Under Normal and Pathological Conditions, Acta tuberc. scandinav. **24**: 264, 1952.

Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty-sixth Annual Meeting of the American Association for Thoracic Surgery will be held May 7, 8 and 9, 1956, in Miami Beach, Florida. Headquarters will be at the Hotel Fontainebleau.

Requests for Hotel Reservations

These should be mailed directly to Mr. Jack Slone, Director of Sales, Hotel Fontainebleau, Miami Beach, Florida. Please mention this Association, the type of accommodation desired, the date and approximate hour of arrival and departure. If accommodations are desired elsewhere in Miami Beach, please communicate directly with the hotel of your choice.

Thoracic Surgical Forum

The Thoracic Surgical Forum will be continued as a special session at the 1956 meeting. The Forum is primarily for the presentation of short papers on current thoracic research, experimental problems, anatomical studies and modified or new surgical techniques. The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers, or to suggest their transferral to the Regular Program.

Papers at this session will be limited to ten minutes, including the showing of lantern slides or other illustrative material. At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper.

All Thoracic Surgical Forum papers will be published together in one issue of the JOURNAL. Maximum length: 3000 words without illustrations. If illustrated, an appropriate number of words must be subtracted for each cut used.

Abstracts for Papers

Abstracts for the presentation of all papers at the 1956 meeting must be received on or before Dec. 15, 1955, otherwise they will not be considered by the Program Committee.

Abstracts should be labeled "For Thoracic Surgical Forum," or "For Regular Program." The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper.

Five, repeat, five copies of *each* abstract must be sent to the Secretary of the Association, Dr. Paul C. Samson, 3959 Happy Valley Road, Lafayette, California. They should not be sent to the Editor.

Those on the program are reminded that papers presented at the meeting *must* be handed to the secretary immediately after their presentation. If they are not ready at that time there is a chance that they will not be published in the JOURNAL OF THORACIC SURGERY.

Motion Picture Session

Provisions have been made to show a limited number of motion pictures to be selected on a competitive basis. *The films themselves,* together with descriptive material concerning length of presentation, etc., must be received by Dr. Julian Johnson, University Hospital, 3400 Spruce St., Philadelphia 4, Pa., before Dec. 15, 1955.

It is planned to run the motion pictures in a smaller room at the same time as the scientific sessions. If the films are well labeled, it will not be necessary for the author to be present for comment.

Applications for Membership

Applications for Associate Membership in the Assocation must be received by the Membership Committee not later than Dec. 15, 1955, otherwise, the applications will be deferred for consideration until the 1957 meeting.

Applicants must be sponsored by three Active or Senior Members of the Association. In addition to the signatures on the application form, the sponsors will forward a *separate* letter concerning the applicant directly to:

Dr. O. T. Clagett
Chairman of the Membership Committee
Mayo Clinic
Rochester, Minn.

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year.